Multi-modal Interaction in Biomedicine

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Abstract. This chapter introduces the concept of multi-modal interaction and our findings related to the development of biomedical applications for two different projection modalities: virtual reality and desktop. The case study for this research is a simulation system for vascular reconstruction - the Virtual Radiology Explorer (VRE). The VRE is an interactive simulation-visualization complex aimed to help in making diagnosis and treatment planning for vascular disorders. To make the system functionality available both in virtual reality and desktop settings, two versions of the VRE have been implemented. We present their qualitative comparison analysis in respect to the interaction capabilities provided. To check, which projection modality complies better with the expectations of potential users of the VRE, and to find out the possible place of the VRE in real life environments, two user groups - vascular surgeons and interventional radiologists – have been interviewed and their daily activities observed. Users' needs, everyday tasks and preferences have been analyzed; the main results are summarized in this chapter. Among others it has been found that the combination of virtual reality and desktop projection modalities within the same interaction-visualization environment may help to satisfy a wider range of the VRE users in comparison to the case, where only one projection modality is used. To finalise the chapter, we discuss three alternative solutions on how this concept can be deployed.

Keywords: multi-modal interaction, Virtual Radiology Explorer, desktop, virtual reality, user profiling

1 Introduction

Everybody agrees that user tasks and preferences should play a central role in the design and development of applications oriented to non-computer experts. Nevertheless, even biomedical applications are sometimes developed in a relative vacuum from the real needs of end-users and environments where they are supposed to be used.

To provide a clinician with an intuitive environment to solve a target class of problems, a biomedical application has to be built in such a way that a user can exploit modern technologies without specialised knowledge of underlying hardware and software [18]. Unfortunately, in reality the situation is different. Many developers do not take into account the fact that their potential users are people, who are mostly inexperienced computer users, and as a result they need intuitive interaction capabilities and a relevant feedback adapted to their knowledge and skills.

User comfort is very important for the success of any software application [13]. But very often we forget that usability problems may arise not only from a 'uncomfortable' graphical user interface (GUI), but also from a projection modality chosen incorrectly for deploying an interactive environment [16].

Existing projection modalities have not been sufficiently investigated yet in respect to usability factors. Meanwhile, the selection of an appropriate projection modality in accordance with the user's tasks, preferences and personal features might help in building a motivated environment for biomedical purposes. In this chapter we summarise our recent findings related to this research and introduce a new concept of multi-modal interaction based on the combination of virtual reality (VR) and desktop projection modalities within the same system. For the case study of the research we used a biomedical application simulating vascular reconstruction [2, 22].

The rest of the chapter is organised as follows. Section 2 introduces concepts of a multi-modal interaction and projection modalities. Section 3 describes the biomedical application for vascular reconstruction deployed for two different projection modalities. Section 4 is devoted to the experiments on user profiling. Both the methodology, on which the user profiling was based, and the results are presented here. In section 5 the possibilities of how VR and desktop projection modalities can be combined are discussed. Finally, conclusions and plans for future research are presented in section 6.

2 Multi-modal Interaction and Projection Modalities

Traditionally, multi-modal interaction is considered as interacting with a computer system using more than one input or output modality at a time, usually suggesting drastically different modalities to be used simultaneously [16]. The simplest example of multi-modal interaction is the simultaneous use of a mouse and a keyboard. More advanced multi-modal interfaces may combine voice input with a mouse and/or tactile feedback.

Today's advanced computer technologies provide different forms of input/output modalities. The possibility to combine them while using the same application leads to the development of a multi-modal interaction style. We may use command-dialogue, speech recognition, data-entry, graphics, web and pen-based interfaces, direct manipulation, haptics, gestures and even interacting via GPRS enabled cell phones. For example, one can draw simple images by walking round the streets of a city and entering data points along the way via a cell phone [25]. Virtual and augmented reality can be also considered as input/output modalities used for providing the interaction-visualization support [16]. These two relatively new interaction paradigms are alternatives to a desktop solution applied on a common PC (or a PDA). They are usually referred to as projection modalities [6].

Virtual reality (VR) is a projection modality, invented in 1965 by Ivan Sutherland [20] and intended to make the interaction process with a computer more intuitive and appealing. The main difference of an immersive[1] [5] application in comparison to a desktop one is that it can provide the user with a sense of presence. In VR an artificial world is created around the user, which gives the impression of being in that world and able to navigate through and manipulate objects in the world [5]. Ideally, VR has to provide an environment, where users can interact freely in a 3D space. However, in practice the utilization depends on hardware and software solutions chosen for deploying this projection modality.

Figure 1. AR in medicine

When VR is combined with the real world, this projection modality is called augmented reality (AR). AR is a combination of a real scene viewed by a user and virtual objects generated by a computer that augment the scene with additional information. So if in VR the artificial world is generated completely, in AR the real world is combined with elements from the artificial one [11]. Actually AR is a projection modality, which is the closest to the real world because a user mainly perceives the real world with just a bit of computer-generated data (Fig. 1).

Figure 2. An example of a medical virtual environment on a desktop: the Philips Medical Systems' "Easy Vision"

As for a desktop, we here refer to a conventional PC. A conventional PC is highly refined to support office work, which is characterized by a user sitting in a chair, at a desktop preferably with a lot of space for a keyboard and a mouse [15]. The user is typically situated at the same desktop the entire day and primarily works alone. In the case of a desktop projection modality, a 3D environment is projected on a computer screen (Fig. 2) and users' manipulation and navigation capabilities become limited within a 2D projected world.

We focus our research on investigation of differences arising from the interaction in VR and desktop environments.

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[1] Immersive VR offers the user a stereoscopic, head tracked, as much as possible surrounding visual experience using either head-mounted displays or (multiple) projection screens, such as in the CAVE environment. Such systems are deemed 'semi-immersive', when an all-around picture is not offered [5]

3 The Virtual Radiology Explorer in VR and desktop

The Virtual Radiology Explorer (VRE) is a biomedical simulation system for vascular reconstruction, which has been deployed both for VR and desktop projection modalities. Unhealthy life style and dangerous habits may affect our arteries and veins. The purpose of a vascular reconstruction is to redirect and increase blood flow in the case of stenosis[2] or repair an artery if it is affected by aneurysm[3]. To find the best solution for the treatment of a particular vascular disorder is not always an easy task and depends to a great extent on the current stage of a disease and the exact location of the affected zone of an artery [21]. The aim of the VRE is to provide a clinician with an interactive virtual simulated environment to visualise and explore the patient's vascular condition to help in finding solutions for further treatment.

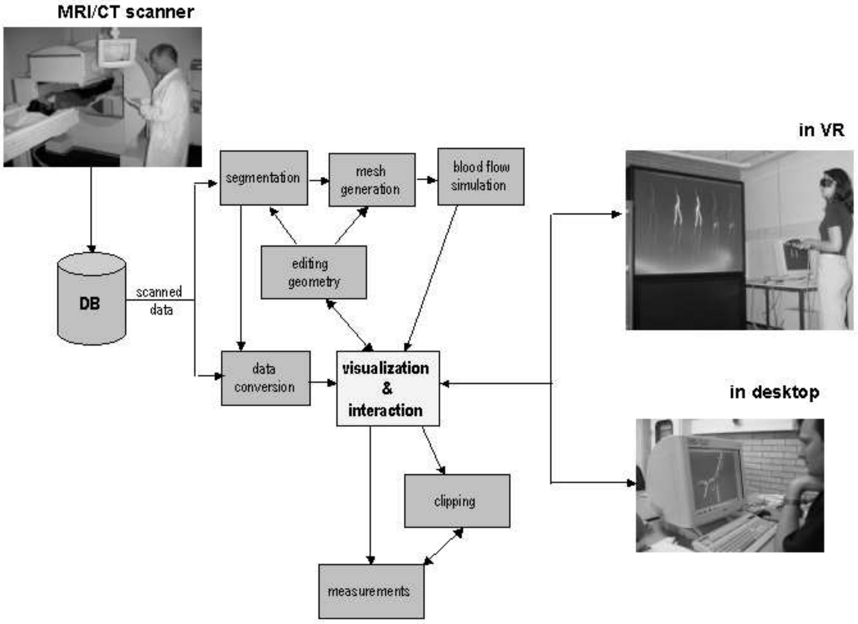

Figure 3. An interactive simulated vascular reconstruction system

The scheme shown in Fig. 3 presents the architecture of the VRE system. The input data for conducting an experiment is a patient's data, which comes either directly from a scanner in a hospital or from a remote storage or a database (DB). By means of the VRE system the end-user may assess medical scans in 2 or 3D, simulate the vascular reconstruction procedure and validate possible ways of treatment by comparing a patient's blood circulation before and after the simulated surgical interven-

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[2] Stenosis is a narrowing or blockage of the artery [21]

[3] An aneurysmal disease is a balloon like swelling in the artery [21]

tion has been applied. The VRE solver simulates blood flow parameters, which are visualised in 4D (time dependent 3D [2]) to give a surgeon a possibility to check whether the blood flow in the affected area will be normalised or not.

Functional element	**Description**
Segmentation	The segmentation is applied to extract the arterial structure of interest from a raw dataset.
Data conversion	At this stage a scanned data in DICOM [17] format is converted into VTK [26] format so that it can be visualised and processed further.
Mesh generation	The segmented and converted dataset is then modified into a 3D mesh for the VRE solver.
Blood flow simulation	The VRE solver simulates the parameters of the blood flow: velocity, pressure and shear stress. The solver is based on the lattice-Boltzmann method, which is a mesoscopic approach for simulating fluid flow based on the kinetic Boltzmann equation. [2, 18]
Grid (geometry) editing	A user may edit interactively the geometry of an artery: add a bypass, remove insignificant elements or restore the fragments lost during the segmentation.
Measurements (probing)	The interactive measurement component of the VRE provides the possibility to measure quantitatively a distance, angle, diameter and some other parameters characterizing an artery.
Clipping	Using clipping planes a user may cut off the display of a scene such that anything in front of the near-plane, or behind the far-plane, is not visible. If needed measurements and clipping can be combined. [14]
Visualisation and interaction	Several visualisation techniques are used within the VRE to represent the patient's data and the parameters of a blood flow. [18] Surface and volume rendering are used for the visualisation of arteries and of the patient's body. We use currently glyphs, streamlines and streaklines to visualise the results of the blood flow simulation. As for the interaction capabilities, the VRE supports two interaction styles: - the Virual Operating Theatre for VR (section 3.1); - a Personal Desktop Assistant for desktop (section 3.2).

Table 1. An overview of the VRE functionalities

The potential users of the VRE are vascular surgeons, radiologists and technologists, as well as medical novice specialists, students, and trainers. [8]

A detailed description of the functionality of the VRE system is far beyond the scope of this chapter. To add to the understanding of the VRE Table 1 provides a brief description of each functional element from Fig. 3. Readers interested in getting more information about the VRE may refer to our earlier work [2, 18, 22].

Many of the VRE components are non-interactive due to their complexity (e.g., simulation, segmentation, data conversion). A user may only run, pause or stop the execution of a routine. As for the interaction capabilities, they are supported currently only by several components of the VRE, namely: grid (geometry) editing, data exploration (e.g., clipping engine) and measurements.

The system is available both on the Distributed Real-time Interactive Virtual Environment (DRIVE) system [1, 22] and on a PC-based workstation. Two independent versions of the VRE have been developed to give a possibility to exploit the system in two projection modalities: in VR and desktop.

3.1 The Virtual Operating Theatre

We called the interaction style of the VRE system deployed for the VR projection modality ‘the Virtual Operating Theatre’, because a user ‘plays a role’ of a physician applying the treatment of a vascular disease on a simulated patient [2].

To support better the user’ interaction within an operating theatre, a multi-modal interface [18] to the VRE system has been built. It combines context sensitive interaction by voice and manipulation of 3D virtual objects using a wand[4] and hand gestures. Although, the main VRE functionality can be accessed both via a direct selection/manipulation and via a voice command, for time consuming procedures related to grid editing, interactive measurements and data exploration the direct manipulation technique remains the most reliable.

For the end-user of the VRE system, grid editing is the most important functionality, since it permits to simulate the surgical procedure of the placement of a bypass[5] on an artery. In VR users are capable to manipulate 3D objects directly. They deal with 3D representations of an artery and a bypass. For representing a bypass we use spline primitives. So the procedure of adding a bypass comes down to re-scaling of a spline and positioning it correctly on an artery. These manipulations are conducted using a wand. The same procedure can be applied to the placement of a stent within an artery in the case of auneurism.

Measurements are crucial both for diagnosis and for planning the treatment. Clinical decision-making relies on evaluation of the vessels in terms of a degree of

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[4] A wand is a hand driven controller combined with tracking sensors to allow the VR system to receive user commands and to track the position of the hand with respect to virtual objects; provides 6 degrees of freedom (position and orientation) [22]

[5] A bypass is a graft rerouting a blood flow around blockages. Usually it is a piece of vein taken from elsewhere in the body or an implant made from an organic material [21]

narrowing for stenosis and dilatation[6] for aneurysms. The shape, length, diameter, and even material of a bypass or a stent depend to a great extent on the size and geometry of an affected vessel.

Interactive measurements in VR are organized as follows. For conducting a measurement, a user has to position an appropriate number of active markers on an object. Markers are building blocks of the distance, angle and linestrip measurements. The number of necessary active markers depends on a measurement to be done. For measuring a distance, a user has to add 2 markers and if it is an angle – 3, for conducting linestrip or tracing measurements – at least 2 [22]. In VR a user can add a marker via direct manipulation using the position and orientation of a wand.

A free clipping engine [12], which has been developed recently as a part of the VRE system, is an interactive component aimed to help in the exploration of big datasets. By restricting a view via a clipping plane the user may look inside of the patient's body or specific part of an artery. In VR a user may change the orientation of a clipping plane by changing the direction of a wand and as a result see the original data, obtained from a scanner, slice by slice (Fig. 4).

Figure 4. Free clipping in VR
(The original dataset was provided by Dr. A. Koning, SARA, the Netherlands)

Using a wand the user may navigate through a virtual world, explore the patient's body and even walk through an artery. However, to navigate and manipulate successfully in a 3D virtual world a user should possess special motor skills, which is not an easy task for all people [6].

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[6] Dilatation is an increase over the normal arterial diameter [21].

3.2 A Personal Desktop Assistant

It is known that the desktop projection modality suits the individual work the best [6]. That is why we called the interaction style provided by the desktop VRE ‘a Personal Desktop Assistant’. In principle a user does not need additional motor skills to interact with the desktop VRE. The biggest problem arises from the fact that within a desktop application we cannot manipulate 3D objects directly, we always deal with 2D projected representations of these objects [7]. Even though, the 3D representation of data is provided by many desktop applications. It does not play an important role with respect to the manipulation or navigation capabilities. It is used mostly as a passive viewer, which helps a user to orient better.

Thus, to add a bypass or a stent within the desktop VRE a user has to deal with several projected representations of an artery and auxiliary dialogue menus. The same concerns interactive measurements in a desktop. The procedure of adding a marker is similar to the procedure of grid editing. If in VR a user can add a marker via a direct manipulation using the position and orientation of a wand, switching to the desktop projection modality leads to the necessity to deploy extra menus and sliders to help the user to orient him or herself in a projected 3D world.

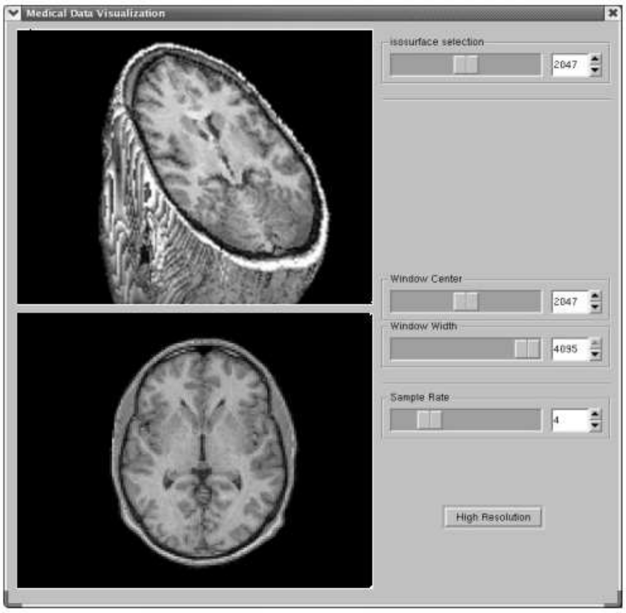

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Figure 5. Clipping in the desktop VRE
(The original dataset was provided by Dr. C. Taylor, Stanford University, USA)

The GUI of the clipping engine of the VRE deployed for the desktop projection modality is shown in Fig. 5. In comparison to VR versions, additional interface capabilities have been applied. Thus, a user may select a slice of interest by means of a menu or a slider. A unique identification number helps to identify a concrete slice. The GUI contains two viewers: one presents the 3D object and another one shows a high-resolution slice of interest, which has been generated as a result of the intersection of a 3D object with a clipping plane built by a user. The combination of these two views provides several advantages. First of all, a user can have a 3D view of an object, which is important for planning a further intervention; and at the same time he or she can get a more-detailed view of a slice of interest by varying scale or contrast parameters. It is also important that the technique used is quite similar to the standard approach for the visualization of CT/MRI scans familiar to the end-users of the VRE [12].

Even though, like it was mentioned above, for the manipulation and navigation in a desktop environment a user does not need to possess extra motor skills, the necessity to deal with the increasing number of GUI's elements may lead at a certain moment to the deterioration of the users' orientation capabilities.

4 User Profiling

The existing prototypes of the VRE provide a sufficient set of functionalities, enabling us to take a much closer look at the usability problems. To make sure that the system is developed in accordance with real life demands, the choice was made to conduct a small exploratory study as a first step to investigate the daily working context of two focus user groups of the VRE: radiologists and vascular surgeons. 7 interventional radiologists and 7 vascular surgeons from 9 Dutch hospitals participated in the experiment on user profiling.

4.1 Methodology

The most effective way to find usability problems of the VRE is the extensive involvement of users in prototyping and development of the system. However, clinicians are not unlimitedly available for extensive design sessions and repeated laboratory testing. The advantage of contextual analysis [3] applied is in studying users' tasks and preferences in a real life environment without having to rely on self-reporting methods.

The combination of exploratory interviews and observation sessions leads to a better understanding of tasks and processes surrounding the diagnosis and treatment planning for vascular disorders. It also permits us to get a better view to the possible place of the VRE system in a real life medical environment.

Observations have been carried out to gain detailed understanding of tasks and the context, in which each task is performed. The whole trajectory of tasks related to diagnosis and treatment planning has been observed in a manner resembling contextual inquiry by an individual researcher [10]. Forms containing data recorded and reported by clinicians in certain assessment tasks have been gathered. Notes and photographs have been taken when possible and permitted.

The interviews served as a preparation for observation sessions. During series of ‘one-to-one’ interviews the subjects have been asked about their daily activities related to diagnosis, treatment planning and surgical interventions. Working processes and information used in these processes have been identified. Current bottlenecks and high-risk elements of each task have been assessed to gain understanding when the system’s support might be useful. The usage of 3D data by subjects has been evaluated. Expectations concerning the improvement of existing medical tools have been gathered. The subjects’ attitudes towards different projection modalities have been analysed.

To summarise, the user profiling permits us to:

- Identify the processes related to the tasks of diagnosis and planning interventions for vascular disorders and specify the place of the VRE with respect to these processes;
- Classify potential users of the VRE and analyse their attitudes towards VR and desktop projection modalities.

The next subsections present these findings.

4.2 Task Analysis

Diagnosis starts when a patient comes to the First Health Care, where a therapist confirms that a patient is suffering from a vascular disorder. At this early stage information processed by a therapist may vary from a story told by a patient to a complete scan dataset made earlier.

The next step is consultancy, which is usually conducted by a vascular surgeon. The consultation includes diagnosis and identification of contraindications with the corresponding explanations for minimisation of risk factors in future (e.g., stop smoking or low cholesterol-level) [8]. Physical examination can be also conducted: it includes measurements of blood pressure and pulse-rhythm, as well as special tests, e.g., the ‘walk test’ [9]. If a vascular surgeon is an experienced practitioner, this examination will be sufficient to make a diagnosis and to plan the further treatment for a typical case, even including a surgical intervention if necessary.

As for non-typical cases, further testing is required, which implies collaborative work of radiologists and surgeons to make correct diagnosis and plan a proper treatment. Several imaging techniques can be used to determine the location of the obstruction or narrowing of the artery. One of them is echo-doppler (duplex) examination. It permits to picture the vein to determine the location of a vascular disorder. The echo-doppler examination utilizes an ultrasound probe to visualize the vein structure either through the chest wall or by placing a probe through the mouth into the esophagus [17].

If the echo-doppler examination does not help in better understanding of the patient’s conditions, computed tomography (CT), magnetic resonance imaging (MRI) or magnetic resonance angiography (MRA) can be used for the further examination

[17]. 3D data acquired by CT or MRI is always converted into a set of 2D slices that can be displayed and evaluated from various perspectives and levels. MRA is a technique for imaging blood vessels that contain flowing blood. It is very popular among cardiovascular specialists because of its ability to non-invasively visualize a vascular disease. The choice of the imaging technique is determined by the structure or anomaly that needs to be observed, given that some techniques are better suited for certain cases than others. [21]

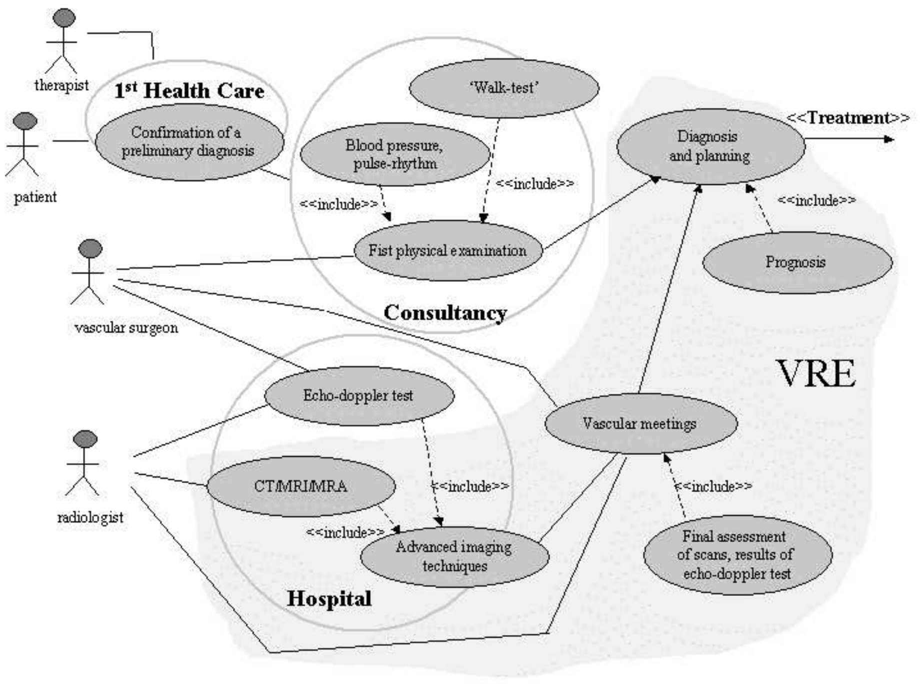

Figure 6. Simplified use-case diagram for the VRE system

Although, the data acquired by imaging techniques is always presented in 2D, radiologists and surgeons can easily process it. However, for complicated non-typical cases 3D reconstruction of scans is also performed to get an extra insight in the geometry. In this respect the VRE system might be very helpful, for the prediction of the behaviour of a bypass or even a stent in the future. In any case, the VRE will always remain only an assistant in making a decision. Nevertheless to the available functionality of the VRE in future, the final decision will be made always by clinicians. Thus, currently the final decision about the diagnosis and further intervention is usually made during a 'vascular meeting' where both radiologists and surgeons are present.

A simplified use-case diagram for the VRE system is shown in Fig. 6. This diagram corresponds only to assisting in decision-making. As for another possibility of using the VRE as a training environment for medical students and novice clinicians, currently it is only possible if the training process is guided and controlled by a teacher, who is a confident user of the VRE.

4.3 User Groups and Types

End-users of the VRE are people, who use the system as a tool for conducting experiments. It is expected that the VRE will be used for the interactive decision support by vascular surgeons, radiologists (both diagnostic and interventional) and technologists[7].

Figure 7. A typical example of a collaborative environment

An unexpected finding of the experiment conducted was the identification of an extra potential user group – technicians [8]. They form one of the most perspective user groups of the VRE, since they currently use diagnosis and planning systems to prepare scan images for radiologists and surgeons, so that they could assess these images as quick as possible. In some cases, technicians and radiologists perform the

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[7] Vascular technologists are people from scientific or radiography background. They conduct patients' testing using special equipment, including MRA/MRI/CT scanners, for diagnosis of arterial and venous diseases.

first assessment of these images together. Depending on the scope of the VRE in future the needs and requirements for this user group may need to be taken into consideration as well.

Like it was mentioned earlier, two user groups participated in the experiment on user profiling: vascular surgeons and interventional radiologists. We tried to categorise people that we interviewed and observed and as a result came up with the following classification of the potential users of the VRE system.

1. *Highly cooperative clinicians*. The work of these people is highly cooperative (Fig. 7) and may require fast intervention. They are very dependent on each other, nurses and anesthetists. It is very important for these clinicians to have access to different types of technology 'on-fly' (e.g., X-ray machines, the electronic patient data, ultrasonic equipment, etc.). The Virtual Operating Theatre is the best solution for this user type. However, it is important to take into account the fact that it is quite possible that they have to remain sterile, then a traditional wand and stereo glasses are not an option for them.

2. *Experts*. These people are usually very experienced clinicians. In making a decision they rely more on their own expertise, than on experience of other people and available technologies. However, it does not always mean that these clinicians are conservative. Many of them can be very enthusiastic about new advanced computer technologies, especially if the results are generated quickly and comply their expectations. This user type prefers individual work, so a Personal Desktop Assistant might be a good solution for them.

3. *Mobile clinicians*. These people move around treating the patients. It can be within a hospital but it could also be in the patients' home. These people are working in different environments with different needs for IT-support (e.g., the ward, the office, the outpatient department, the meeting room, the patient home). This user type is mostly interested in monitoring the patient's condition. Although, from time to time they can be interested in getting a quick access to the VRE system. The best solution for these clinicians is the VRE deployed for the desktop projection modality available on a PDA.

4.4 User Attitudes towards VR and Desktop

Different people prefer different interaction styles. The Virtual Operating Theatre cannot always satisfy all potential users of the VRE, as well as a Personal Desktop Assistant. The choice of an interaction style is very closely related to users' tasks and preferences. We base this assumption on the results of user profiling. Both interviews and observations indicate that many surgeons and interventional radiologists would prefer to use desktop applications for accomplishing every-day tasks. As for the large immersive virtual environments, they would be more preferable for collaborative work and training.

Even though 3D visualization is now available in most hospitals, it has been found that existing systems are not always in use. Currently, no intervention is carried out based on the evaluation of 3D visualizations only. This is due, first of all, to the bad resolution of 3D stereoscopic images in comparison to 2D high-resolution scans.

The advantage of the VR projection modality is that it provides possibilities for collaborative work, which is crucial if we talk about clinicians. During observation sessions it has been found that medical people spend significant part of their time in collaboration: for making a diagnosis and planning a treatment. However, the number of people involved in a work discussion as usual does not exceed a group of 5 people. The exception is a weekly medical conference, in which all staff members of the medical department are present.

VR	**Desktop**
A sense of presence is important for accomplishing a task.	Users need to switch quickly in between tasks.
Stereoscopic visualization and 'sense of immersion' add significantly to the task understanding or performance.	Stereoscopic visualization and immersion do not add to the task understanding or performance.
The 3D stereoscopic representation is vital.	Image resolution is crucial.
Insight view into a complex structure is more important than performance.	Performance is vital. No extra time can be spent for running the specialised equipment or conducting complicated manipulations.
Perception and field regard are important.	Perception and field regard do not add to the understanding of a task
Collaborative work of a relatively big group of people (3 or more) is necessary to support.	Quick, informal collaboration needs to be provided for a relatively small group of people (2 maximum).
End-users are interested in new technologies and willing to spend time for training.	End-users are less inclined to learn using new equipment and technology.
There is enough space to place equipment.	Space limits.
Enough budget is available	The available budget is limited.

Table 2. Generic criteria for choosing between VR and desktop projection modalities

A desktop application cannot be treated as an instant solution to usability problems experienced while working with a VR application [7], and vice versa. Success always depends on the usability of a desktop or VR version. However, the better understanding of the interaction capabilities provided by the desktop projection modality makes it a viable alternative to VR. Another factor is simulator sickness[8].

Simulator sickness occurs in conjunction with VR exposure. Users having simulator sickness cannot work in VR for a long time. According to [6] almost a quarter of computer users suffers from a form of simulator sickness. So approximately the same proportion of the VRE users is not capable to exploit it in VR. For these users desktop solution remains the only possible option.

The heuristic evaluation of the VRE [13] coupled with the results of user profiling permit us to pick up criteria helping to choose in between VR and desktop. Some of them are provided in Table 2. More information can be found in other publications [6, 12]. These criteria can be applied not only to biomedical applications, but to another domains as well, especially if the interaction and visualisation aspects are vital for the application under the development.

5. VR and Desktop: an Integrated Solution

The results of the experiments on user profiling led us to the idea to combine VR and desktop projection modalities within the same interaction-visualisation system. In this case different types of users will be able to work within the same environment and switch in between different projection modalities if necessary. We see at least three possibilities of how this idea can be deployed.

One of the possibilities of how VR and desktop applications can be combined is shown in Fig. 8. The main idea here is to provide access to an already existing desktop application by “absorbing” its GUI into VR [1, 4]. A desktop application is represented in a separate window. For its activation and further manipulations a user has to use a wand and (or) a keyboard, which is not very intuitive and quite often leads to the significant meshing of the interaction process. Thus, if the position of a ‘desktop window’ in VR is not fixed, it is very easy to loose it while navigating in a 3D world.

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[8] Simulator sickness is a kind of motion sickness except that it occurs in a simulated environment without actual physical motion [16]

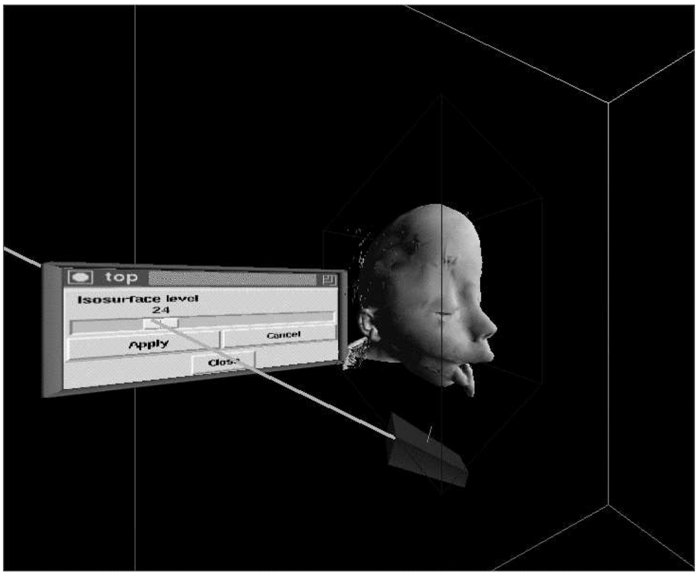

Figure 8. Combination of VR and desktop within an immersive virtual environment [1] (The image is courtesy of Dr. R.G. Belleman, University of Amsterdam, the Netherlands)

Other possibility is to provide a user with an integrated workplace, where he or she can work in the virtual environment and at a desktop PC at the same time. Working alternating at a desktop PC and at a VR installation is the typical situation for a programmer and also for a CAD-designer (e.g., the PI-casso system [19]). Because of repeatedly putting up and down input devices and glasses and also due to repeatedly standing up and sitting down when changing the workplace, this is very demanding and time consuming.

A Personal Space Station (PSS) is a relatively new concept for deploying the interaction-visualisation support [15]. The main advantage of a PSS is that it initially combines the elements of VR and desktop projection modalities within the same system and it is possible to switch in between if necessary.

Figure 9. A Personal Space Station – an experimental set-up [24]

A PSS allows users to interact directly with a virtual world. A PSS consists of a semi-transparent mirror, in which a stereoscopic image is reflected. A user reaches under a mirror to interact with the virtual objects directly with his or her hands or by using task-specific input devices. Fig. 9 shows the experimental set-up of a PSS that has been built at the University of Amsterdam. By definition a PSS is an individual environment, but there is a possibility to build a shared environment, where users can manipulate the same virtual objects working on different PSSs [7]. More information about a PSS concept can be found in [24].

The idea to combine VR and desktop projection modalities on a PSS sounds very attractive to us. However, its deployment is not an easy task. Now both the VR and the desktop versions of the VRE system can run on a PSS. But to switch a user has to restart a system, which is very uncomfortable and does not allow using the functionality of both versions at the same time.

The interaction in VR and desktop projection modalities is different with respect to navigation, locomotion, manipulation and measurement capabilities [5]. To combine the Virtual Operating Theatre and a Personal Desktop Assistant, a PSS has to support input and output modalities providing by both VR and desktop simultaneously. This leads us to the development of a new concept of ‘a multi-modal desktop-

VR interaction'. This concept is based on the principle of exploiting interaction capabilities of VR and desktop simultaneously without changing devices and a workplace.

6 Conclusions and Discussion

In this chapter we introduced our findings related to the development of biomedical applications in different projection modalities. The case study for this research was a simulated environment for vascular reconstruction – the VRE system.

The heuristic usability evaluation that we conducted recently and the first results of user profiling indicate that the human-computer interaction depends to a great extent on a projection modality chosen for deploying interaction and visualisation capabilities. It becomes especially crucial if we talk about biomedical applications. As clinicians are usually unfamiliar with modern computer technologies, it is very important to make the process of their interaction with an application as much intuitive as possible.

In this chapter we introduce the concepts of multi-modal interaction and projection modalities. We discuss two interaction styles of the VRE system based on VR and desktop - the Virtual Operating Theatre and a Personal Desktop Assistant. Although, both VR and desktop solutions are viable alternatives for the VRE users, the results of user profiling show that any of them cannot satisfy all potential users. That is why we decided to combine virtual and desktop interaction capabilities within the same environment. We are now working on deploying a Personal Space Station that will be capable to provide 'a multi-modal desktop-VR interaction'.

Our current research goal is to build a system, which will give users a possibility to switch in between VR and desktop projection modalities without changing devices and a workplace. We focused on the development of a mechanism to support simultaneously input and output modalities of both VR and desktop. This will permit us to provide end-users of the VRE with a combined desktop-VR version of the system. We expect that it will help to satisfy the wider range of end-users and make their interaction with the VRE more intuitive.

Our next research step related to HCI will be to compare navigation, locomotion, manipulation and measurement capabilities in VR and desktop projection modalities with respect to users' satisfaction, performance and mistake inflicting. We plan to use the VRE running on a PSS as a case study for this research.

The final research goal will be to develop a system able to dynamically change the interaction style, adapting itself to the situation, preferences and motor skills of each user. This system will be based on personalized interaction metaphors [23].

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