Virtual reality for physically disabled people

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VIRTUAL REALITY FOR PHYSICALLY DISABLED PEOPLE

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Abstract—This paper demonstrates how physically disabled people can benefit from the innovative Virtual Reality techniques. Several specific examples show the applicability of Virtual Reality to therapy and rehabilitation of various disabilities. In addition, the paper describes how physicians can use Virtual Reality as an advanced visualization tool for the diagnosis of physical disabilities. Finally, possible display techniques and input devices for diagnosis and rehabilitation purposes are discussed briefly.

Virtual Reality physical disabilities motor disturbances

speech disabilities assistive technology advanced visualization tools

INTRODUCTION

Virtual Reality aims at addressing as many human senses as possible. Generally speaking, the term Virtual Reality (VR) describes a computer-generated scenario of objects (virtual world) the user (here patient or physician) can interact with. In contrast to 'conventional' man-computer interfaces the interaction is designed in three dimensions rather than two. The combination of three-dimensional computer graphics, special display techniques (head-mounted display or stereo glasses) and specific input devices (spaceball, dataglove, etc.) allows intuitive manipulation of objects in the virtual scenario, thus giving users the impression of being part of the scenario.

The use of VR for physically disabled people comprises two aspects: the interaction with the patient and that with the physician. In the following, examples for both issues will be given and described in detail. Finally, suitable display techniques and input devices of VR-based systems are discussed briefly.

PATIENTS AND VIRTUAL REALITY

VR is of special interest for patients showing dysfunction or complete loss of specific 'output functions' such as motion or speech in two ways. First, patients can be brought into virtual scenarios where they can perform specific tasks - either simply to measure their performance for diagnosis (e.g. duration or accuracy of movements) or to train certain actions for rehabilitation purposes. Second, VR input devices like a dataglove, originally developed for interaction within virtual environments, can be used by patients as assistive technology tools to act in real world (e.g. 'translating' hand movements into speech as described below). In the following, the possible areas of use of VR for some specific disabilities will be shown.

Motor disturbances

Patients suffering from motor disturbances like *pareses* can benefit from Virtual Reality techniques in various ways. Here, VR can be applied for rehabilitation of specific disorders by training exactly those functions that are disturbed. This can be done by creating virtual scenarios, in which series of motor tasks are generated. VR based tests can be accurately graded, realizing a smooth transition from simple, low-dimensional to more complex motor tasks. An additional motivating effect for patients arises from the precise feedback of their success in real time. In projects at Rutgers University, Loma Linda University and Greenleaf Medical Systems, USA, VR datagloves are already used successfully for rehabilitation purposes [1,2,3,4,5,6].

A very popular concept is that of Biofeedback, where patients are trained to control activation of single muscles, measured by EMG. Some investigations [7,8,9] hint, however, that progress in abstract biofeedback paradigms not necessarily enhances daily practical performance: 'To learn, one has to act on the world' [9]. To avoid these problems even for severe handicapped patients, VR seems to be especially suitable. J. P. Wann at Edinburgh University has developed a real-time computer feedback system (RTF) for children suffering from *cerebral palsy* using muscle signals for controlling different game-like scenarios. First results [9] show significantly better performance of children trained with RTF in comparison to those trained with a more conventional therapy scheme.

Apart from ‘low-level’ dysfunctions like pareses, there are some higher-order disturbances, one of which is *apraxia*. An apraxic patient has lost the capability to spatially and/or temporally organize and coordinate movement sequences [10]. Apraxias can arise from lesions of human cortex, often accompanied by elementary motor disturbances. In such a case, up to now single testing of the underlying ‘mental motor images’ is not possible as the execution requires the use of the patients’ own motor system. In cooperation between the Institute of Technical Computer Science in Aachen and the Department of Neurology in Duesseldorf, the authors are developing a VR based system for the more precise assessment of apraxias [11]. Virtual scenarios are created in which apraxic patients have to perform specific tasks, e.g. grasping an object. Providing different input technologies (3D tracking devices, spaceball, computer mouse) to control complex movements, it should be possible to separate the different levels of movement planning and execution.

Ataxic patients have problems the other way round, facing an intermodal conflict: They cannot match information received by their proprioception with their visual input, resulting in disturbances of posture and goal-directed movements. Thus, patients often try to compensate their failure by neglecting the information received from proprioception. San Raffaele Hospital in Milan, Italy, tries to train these patients to rely more on their proprioception by presenting them virtual environments with strongly distorted visual cues [12].

Paralyses

Within virtual worlds *paralysed people* are able to perform the same complex tasks as non-handicapped people using input devices that are well suited to their remaining motor capabilities. Assistive technology devices have already been developed that measure minimum human output. H. Lusted and B. Knapp from BioControl Systems Inc. offer a special device called BioMuse providing a direct link between human biosignals (EMG, EEG) and the computer [12,13]. D. Warner at Loma Linda University already employs this technique allowing quadriplegic persons to perform considerably complex actions within virtual environments, e.g. moving objects [14]. It is imaginable that in the future handicapped and non-handicapped persons act and communicate within a shared virtual environment where physical disabilities are no longer recognizable.

Hines Rehabilitation and R&D Center have developed a Virtual Reality system for testing buildings for their usefulness for wheelchair-bound people before they are actually built. Displaying the virtual rooms using a head-mounted display (see below), one can move around using a wheelchair and check for potential obstructions (doors too narrow, cabinets too high, etc.).

Speech disabilities and visual defects

Patients with *speech disorders* or *disabilities* can benefit from a ‘redirecting’ of output channels. Several groups are developing systems where VR-datagloves are used to record gestures for translation from sign language into written text or even spoken words (created using a speech synthesizer)

[15,16]. At the Institute of Technical Computer Science in Aachen a system is developed replacing the dataglove by video camera [17]. Currently, arm and hand still have to be prepared, e.g. using white gloves with coloured markers, in order to get sufficient contrast for the video recording (Fig. 1).

Dysfunctions of the visual system, especially *strabism*, are worked upon at San Jose State University. They propose to use the ‘BioMuse’ input system (see above) in order to determine the degree of misalignment of the eye axes. In a second step, the information gained in this way can be used for training and exercising eye muscles by keeping objects in a virtual environment aligned [12,18].

PHYSICIANS AND VIRTUAL REALITY

The main advantage of VR for physicians is the provision of sophisticated presentation facilities to support them during the diagnosis procedure. VR allows a three-dimensional visualization and manipulation of medical data which can be explored interactively by the physician.

The authors are developing an advanced visualization system employing the graphic facilities of a VR workstation in the field of analysis and diagnosis of movement disorders like pareses and apraxias [19]. While patients perform motor tasks within a real or virtual environment, trajectories are recorded which can then be visualized to the physician in three dimensions for diagnosis purposes and therapy planning. It is possible to move around in space to look at the trajectories from different viewpoints, enabling the physician to understand the very specific of the motor deficit. Besides, the patient’s motions can be animated within VR at different rates, allowing precise assessment and interpretation (Fig. 2 and 3).

Furthermore, VR can be used as a more adequate technique for the interactive exploration of tomography data. The Vox-L stereoscopic workstation developed by J. S. Lateiner makes it possible to display and explore the three-dimensional structure of body areas recorded by medical imaging hardware (MRI, PET etc.), avoiding current restrictions to single slices [20]. Especially regarding movement disorders caused by lesions of the brain, precise analysis of the dysfunction in combination with the examination of the areas affected could result in a much more profound understanding of structure-function relations.

TECHNICAL ASPECTS

In the following, the VR techniques used by the authors are described in more detail to give the reader an impression of technical requirements. The system is based on a Silicon Graphics Iris Indigo 2 Extreme UNIX-Workstation, which provides the necessary computing and graphics performance for the generation and presentation of VR scenarios.

Display techniques

Three-dimensional visualization is achieved using a stationary, high resolution graphics monitor in combination with stereo shutter glasses (Fig. 3). The monitor alternately shows images for the left and the right eye, while the glasses darken the right and left lense respectively. In addition, by measuring head movements, motion parallax is made use of to create a holographic effect (Fig. 4) [21]. The user has the impression to look through a real window, being able to look around objects in VR.

Both for patients and physicians, this display technique is preferred to a technique using a head-mounted display (HMD), consisting of two small monitors installed in a helmet. From our experience, even healthy persons are frequently irritated by the complete loss of visual contact to real environment [22]. Furthermore, visual deficits following the wearing of a HMD have been reported [23].

Input techniques

Movements of physically disabled people have to be measured for interaction with objects in virtual scenarios as well as for later diagnosis by the physician.

In the authors' project a VPL Research dataglove measuring finger movements in combination with an electromagnetic Polhemus tracking sensor for the wrist was tested. It turned out, however, that both devices do not provide data of sufficient accuracy and temporal resolution for a precise assessment of motor deficits. Therefore, the authors now use an optoelectronic position tracking system (Selspot II), where cameras record the positions of infrared light emitting diodes attached to the patient's body. In the longer term non-intrusive methods like video based motion analysis should be used to avoid that patients have to be 'cabled' [17].

A different set of experiments requires the use of a spaceball, a joystick-like device recording six degrees of freedom (translation and rotation in three dimensions). By this, objects and movement in virtual environments can be controlled in a very intuitive manner. The spaceball is also used during motion analysis, enabling the physician to look at trajectories from different viewpoints (Fig. 3).

SUMMARY

It has been shown where Virtual Reality techniques can be sensefully applied in the field of physical disabilities. Virtual scenarios can be created, in which patients suffering from motor disturbances like pareses or apraxias perform motor tasks for diagnosis and rehabilitation purposes. Therapy of ataxia and strabism can also profit from special VR facilities. Using VR datagloves people with speech disabilities can communicate by hand gestures, which are translated into spoken words. In combination with special devices that measure minimum motor output or even human biosignals, VR is an adequate assistive technology for paralysed people. Furthermore, VR technology can serve the physician as an advanced visualization and animation tool for the diagnosis of physical disabilities.

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