Rehabilitation after Stroke using Virtual Reality, Haptics (force feedback) and Telemedicine.

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Abstract. We have constructed a haptic immersive workbench to be placed in the patients’ home for daily adjusted rehabilitation. We also propose a system for Internet based connection and communication between patients and between patients and a clinical rehabilitation center and clinical assessment/evaluation centers. The benefits of a system for rehabilitation after stroke, based on VR, Haptics and Telemedicine should be: increased quality of life, lesser isolation, feeling more secure, fewer tiring transportations, more frequent exercising, better compliance to training, lower cost for transportation. The long term recovery for a larger group of patients with motor impairments is presently under evaluation.

Key words: haptics, home care, rehabilitation, stroke, virtual reality

1. Introduction

We employ contemporary ICT (Information and Communication Technology), Virtual Reality, Haptics and Telemedicine, in our research to develop: 1) A precise quantitative assessment tool and a training device for neurological impairments, especially for stroke patients. The tool will be a low cost set-up that can be distributed to the patients’ housing on a lending basis or be placed at local “activity centres”. 2) Assessment and training programmes/routines for this tool. 3) Telemedical routines for daily “I see you, you see me” communication between the patient and the rehabilitation clinic, for retrieving assessment data from the patient and for tuning the patient’s training exercises. Presently, we have a functional laboratory set-up for parts 1 & 2, above, and have started clinical trials with patients for part 3.

Stroke is one of our most widespread diseases and the principal cause of permanent physical impairment in the adult population (1). The number of persons that will suffer from stroke is anticipated, by 2020, to have shifted stroke from the 6th leading cause of lost disability adjusted life years to the 4th in the world (2). With rehabilitation most patients improve considerably and can increase their quality of life (1). During the post acute phase patients are living in their homes or in other non-
hospital housing. There are well-functioning assessment and treatment procedures for rehabilitation after stroke, but they have some disadvantages. One is the fact that they seldom record movements precisely. Most of these procedures are designed for use in clinical settings, and are therefore not commonly used in the patients' homes or extra hospital situations, like local activity centres. These conditions hamper the regularity in training or force the patients to frequent travels to and from clinics. These travels are tiring for the patients and costly for the society.

A new treatment strategy that so far has not been tried to any greater extent in rehabilitation is Virtual Reality (3-7). The method implies that in a computer environment it is feasible to create a virtual three-dimensional world. Besides the visual component it is also possible to integrate “virtual” touch sensation or force feedback to the hands. This latter technique is named Haptics. Here one can actually feel the objects that are handled, this in addition to the visual perception. The user gets an impression of the three-dimensional interface as being natural. This experience is created by the co-localisation of senses in the virtual set-up. The user works with tools in the hands in a realistic environment, exactly like he/she had the hands inside the computer screen. In our laboratory set-up the virtual environment consists of a haptic equipment that looks like a stylus shaped instrument attached to a lever system freely movable in all directions (figure 1). Thus, the user can see, feel and handle virtual objects like they were real objects. The user gets the feeling of being integrated in a simulated environment (7). Continuously the haptic device record all positions, movements and forces, which are stored in the computer for further processing, analysis and assessment. Built into the haptic system are motors and vibrators that can produce the sense of gravity, friction and elasticity.

The aim of the project is that this rehabilitative service could promote the learning of arm motor abilities at distance from the health facilities. In this way the healthcare professionals are able to continue the treatment and the initiated rehabilitation program. All components of the proposed project exist in prototypes or are developed. Presently, we cooperate with Sensegraphics (sensegraphics.se) in order to develop our hard- and software and to evaluate the possibilities to implement this system in health care organisations and in patients’ housing.

2. Material and methods

2.1 Experimental System

A scenario for the use of such a telemedicine system is the following. The clinic supplies the patient with a portable telemedicine system (Figure 1) at the time of the discharge from the hospital. Back at their home the patient will be able to exercise freely at their own suitable time and in a familiar environment. At specific exercise hours the therapist can monitor and coach the patient from a distance. In this way the healthcare professionals will have an opportunity for feedback about patients’ rehabilitation progress and have the opportunity to make necessary adjustments to the
rehabilitation programme. The proposed system consists of three major components outlined in Figure 2; a home rehabilitation system, a larger hospital rehabilitation system and a clinical evaluation unit. The home and hospital systems use Sensegraphics virtual reality solutions that use the technology called haptics to allow users to see and feel objects that exist only in the computer's memory. The rehabilitation systems will feature a library of engaging activities and “games” that are simultaneously entertaining for the patient and beneficial for rehabilitation; i.e. the games will train certain movements so that the patient can perform their daily training exercises in a fun and stimulating environment.

2.2. System components and connections (Figure 3)

2.2.1 Patient Database System

The patient database system is a central database server that maintains an archive of all patient information. This database is accessible to the rehabilitation staff in order to allow them to plan a rehabilitation program for patients. The data can also be useful for research studies into various aspects of the rehabilitation process.

Data stored in the database would include:

- Results of each game, number of times run, performance for each run
- Raw hand movement data, captured at 1000Hz, for every run
- Game events time stamped to match the raw hand movement data

2.2.2 Rehabilitation Management System

The management system is a computer that acts as a front-end to the game library, patient database system and training systems. From the management system, staff can observe and graph patient’s progress, prescribe games to be played by each patient and communicate (using audio and video links) with patients.

2.2.3 Patient Assessment

A Clinical Evaluation Unit will be implemented allowing rehabilitation staff to measure and monitor the patient’s performance during assessment runs. Assessment runs will be performed using the standard training games run on the standard hospital based training system. All games will, by default, generate time-stamped motion data (x, y, z, yaw, pitch, roll and button press information) at 1000Hz. This data is stored together with time / date and patient information for subsequent analysis.
2.3 Telemedicine platform.

A client/server system will be constructed, based on two standard computers, high performance web cameras, microphones, a SQL database and a high-speed digital loop technology network. The system uses protocols within the TCP/IP suite and enables the transfer of real time system data and log files that shows the patients result, and data concerning video/audio teleconference between the patient and the clinical personnel.

3. Results

The data stored by the system can provide the rehabilitation therapist with an objective view of the patient’s progress and the effect of the therapy. The report of the patient’s activity includes all the relevant information and data graphs (fig 4 and 5). This version of the web data portal was intended for research use, and was designed to be easy to use and powerful enough to provide enough flexibility.

Besides raw-data graphs, the system provides the movement data that is captured in position (x, y, z) and orientation (yaw, pitch, roll) of the haptic stylus together with a time-stamp and any application event messages that may be useful in subsequent interpretation of the data. In figure 4, a movement of the stylus/hand is recorded.
illustrating the range of kinematic responses for one movement unit at baseline (A), during intervention (B), and at follow-up (C). The visual inspection reveals a variation in movement pattern for all patients, especially the end-point (black circle) suggests a different planning process for striking the target.

A simple utility is provided that allows for extraction of interpolated movement data at a rate slower than 1000Hz, as well as determining trajectory length, velocity and acceleration information. In figure 5 is a chart exemplifying hand movement velocity at continuous stages of rehabilitation, which present the patient’s performance in each trial compiled across trials, blocks, or days. Basically, these are the graphs that show whether or not the patient is improving. Trial performances are computed after each trial is finished and stored in the database.

4. Discussion

The increasing costs of providing healthcare services to an ageing population and changing pattern of use of hospital resources, i.e. fall in the average length of stay, are shifting the focus of care from hospital to home or nearby community centres. This current trend of cost containment in healthcare has prompted a search for innovative methods of providing quality care. One method is the use of telemedicine. A modern telemedicine communication technique has the potential to improve the communication and prolong the contact with the patient after being discharged. Telemedicine systems minimises the barrier of distance, and makes it possible to be able to conduct evaluation and rehabilitation program at rural locations, at great distance from the clinic.

This solution is also able to monitor every tiny movement made by the patient while using the system, which can be recorded and sent back to the hospital (Figure 3). Such data is invaluable in not only monitoring the patients progress, but in creating a knowledge-base of stroke victims and even being able to validate drugs that may help stroke or even other neuromuscular victims.

Keeping the application web-based brings a number of advantages, i.e. the service could be offered at the same cost without regards to long distance telecommunication facility charges. Furthermore, a web-based implementation should allow enough bandwidth when it comes to simultaneous video conferencing and precise data acquisition mode in the rehabilitation system, even when the web connection is temporarily low (buffer system). In this client/server system the server reside in the clinic and the clients in the patient’s homes or at a community rehab centre.
clients, placed at a distance from the clinic, will get an input signal from the haptic device, when the patient is doing the exercises. These signals are then computed, acquired and then, within the TCP/IP protocol transmitted through a high-speed digital loop technology network to the server on the clinic side of the connection where it can be examined and evaluated in real-time. This system allows real-time monitoring of the exercises. Furthermore these data is stored in a SQL database. By this system the values of the progress in the exercises can be easy stored and look up on for further examination and evaluation. Besides sending the images from the exercise program the therapist also will have the opportunity to have an ongoing video conference through the session. With the help of this telemedicine system the therapist can actually watch the patient exercising in real time by distance at the clinic, follow the progress and be able to support and coach him/her through it with the help of the video conference service.

5. Conclusion

The benefits of a system for rehabilitation after stroke, based on VR, Haptics and Telemedicine should be: increased quality of life, lesser isolation, feeling more secure, fewer tiring transportations, more frequent exercising, better compliance to training, lower cost for transportation.

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