The virtual reality system used for upper extremity rehabilitation

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Abstract—This paper presents a complete Virtual Reality (VR) system used for upper extremity rehabilitation. The system consists of sensors, the computer application and stereoscopic display glasses. The system is designed to cooperate with special mechanical orthosis used for arm rehabilitation. Patients can see their movements in the 3D virtual space during exercises. The system has a key role in development of rehabilitation robot, because numerous researches show that exercises in VR decreases the time of rehabilitation.

I. INTRODUCTION

Rehabilitation is usually a very complicated process, which lasts for a long time. There are, however, methods to decrease this time period. One of the newest researches shows that time of rehabilitation can be decreased by application of VR. It is partly connected with the fact that patients are not bored while practice in VR environment. Another reason is associated to recovery process in patients’ nervous system. Taking it into consideration, scientists have been working on this problem for a long time now.

Connecting VR with rehabilitation robots is not an easy task, because it involves extensive knowledge from different disciplines e.g. robotics, mechatronics, computer science and game graphics. This is why such systems are not very popular. Small number of the systems which have been adopted to the real robots have usually very simple graphics and the scenario of a game is not very complex. The example of a similar, described system can be computer application in ARMEO [1] or MJS [2] robots.

Despite the fact that many computer companies working on computer games spend millions of dollars on productions, they do not produce games that could be helpful in rehabilitation. Fortunately, there are scientists who develop systems, that are worth attention and that could be useful in rehabilitation. One of the most interesting projects was developed by scientists related to ETH Zurich [3]. They have created complete Activity of Daily Living (ADL) system, that have been successfully used in rehabilitation. Another good examples can be found in [4], [5], were VR systems are presented. Budea et al. created a VR system, which has been connected to haptic interface [6]. Bardorfer studied VR system in context of upper limb rehabilitation [5], similarly Perry created a system for special upper limb exoskeleton [7].

Developed VR environment is an integral part of a rehabilitation robot used for upper extremity rehabilitation [8].

II. GENERAL CHARACTERISTIC OF THE SYSTEM

The ADL system presented in the paper consists of the mechanical orthosis for upper limb, in joint which there are located BLDC drives with encoders. The hand lies on a special handle (called ADL handle), which is also equipped with encoders. These encoders communicate with low-level controllers, which count pulses of the signal and put them into one data vector. Vector is then sent to the high-level controller. BLDC motors communicate through CAN interface. Signals from encoders are sent to a computer program, which shows movement in VR computer system. The images are then transmitted to the VR glasses (Vuzix Wrap 920), which display it on special LCD screens. The glasses are also equipped with accelerometer and gyroscope that transmit position and orientation of a head to the system. The movements of head change the orientation of global coordinate system of VR environment, while the signals from encoders cause the movement of virtual hand (Fig. 1).

III. VIRTUAL REALITY ENVIRONMENT

In order to fulfill rehabilitation purpose, there was created a special computer game. The application was written in OpenGL in C# code. The aim of the game is killing little monsters which appear on the screen in random positions. The area in which monsters can be seen is defined by radius of sphere. The placement of sphere and its radius can be easily changed in relevance to rehabilitation procedure (Fig. 2).

Objects are shown one at a time, after the previous one is killed. After that the monster disappears and appears in a different position. Patients should move their arm and hand in order to proper imposition of the gun. This movements are of course closely connected with the rehabilitation process.

IV. ORTHOSIS

The orthosis is a structure with a rotary joints to which upper extremity of the patient is linked during rehabilitation. It consists of upper and lower part. These parts are constructed from ballscres and long nuts. The length of the parts can be automatically regulated by DC motors with gears. The orthosis had 4 active DOF. Three of them are responsible for
Fig. 1. General scheme of the control system.

Fig. 2. Developed Virtual Reality Environment used for training patients.

glenohumeral joints movements and one joint is responsible for flexion/extension of the elbow. The orthosis is attached to an XYZ linear gantry system, which is moving actively during rehabilitation. Therefore the mobility of the shoulder joint of the orthosis is similar as in the patients’ upper extremity. The orthosis has also simple mechanical limiters of ranges of motion. These are discs with threaded holes into which bolts can be screwed. It is the last line of the multi-modal mechanical safety system. Robot is designed to perform passive, as well as active mode of rehabilitation (assisted by motors) (Fig. 3).

V. ADL HANDLE

The handle consists of three mutually perpendicular axes (Fig. 4). ADL-handle, similarly to orthosis, can also change its length of two links, but unlike in the orthosis, it has to be done manually. Because of this, hand movements can be transferred to the computer system. These hand movements are especially important with application of e.g. pouring coffee from a jug, using scissors and other activities connected with everyday life. The ADL application try to engage the greatest amount of hand movements.

Used encoders have high resolution - 3600 pulses per revo-
Pulses from encoders are counted by special low-level controllers with quadratic counter. After that signals are transmitted to a high-level controller (PC computer) through UART-USB protocol.

VI. EXPERIMENTS AND CONCLUSIONS

The experiments consisted of several game sessions, in order to identify the feelings and comments of users mainly about kinematic configuration of orthosis and ADL-handle, as well as computer application (Fig. 5). Therefore experiments have been made in passive mode only (signal was obtained from the encoders, without the use of BLDC motors). After conducting these experiments, conclusions have been drawn.

Orthosis and ADL-handle are good suits to different anthropomorphic patients parameters. Patients pointed out that ADL-handle should be improved. Because of backlash in the joints, movements have not been perfectly recreated. This is the most important problem to be solved. Some users also complained about low graphics and degree of difficulty of game scenario. However, users who have tested other systems, for example MJS system [2], praised the system for complicated scenario and good graphics. These opinions are therefore relative.

VII. FUTURE WORK

Future work will focus on improving the graphics of games, as well as providing new game scenarios. More realistic graphics will probably have better effect, because it will affect patient’s central nervous system more efficiently.

Equally important is upgrading system on another scenario, what means by creating a new game based on developed graphic engine. This is a natural step to future improvements. This will enable more patients to fulfill their game expectations.

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