Robotic assisted rehabilitation in Virtual Reality with the L-EXOS

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Extended Abstract: L-Exos (Light Exoskeleton) is a force feedback exoskeleton for the right human arm developed at PERCRO. The exoskeleton is designed to apply a controllable force of up to 100N at the center of the user’s hand palm, oriented along any spatial direction. L-Exos has 5 DoFs, 4 of which are actuated and are used to define the position of the end-effector in space. The 5th DoF is passive and allows free wrist pronation and supination movements. The system is fully backdrivable thanks to its tendon transmission.

Figure 1 The L-Exos system worn by a user

In this paper we present the results of a preliminary protocol based on 9 post-stroke chronic patients exposed to Virtual Reality therapy with the L-Exos. The therapy treatment lasted for six weeks with two sessions per week. The L-Exos device was integrated with a projector used to display on a wide screen – placed in front of the patient - different virtual scenarios in which to perform rehabilitation exercises.

Figure 2 Two moments of the rehabilitation therapy with one patient

Three Virtual Rehabilitation exercises were developed using the XVR Development Studio. The first exercise consisted in a robot aided exercise of reaching. The patients were

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asked to reach several targets disposed along an horizontal row, with active assist provided by the robot. The second exercise consisted in a contour following task, where the patient constrained or not by the robot, was asked to move along a circular trajectory, with different geometries. The third exercise consisted in the composition of a 3D puzzle in Virtual Reality.

In all the exercises the robot was capable of compensating for the weight of the upper limb of the patient and to provide an amplification of his movement according to the ability of the patient at the enrollment stage.

![Figure 3](left) A screen shot from the first “reaching” exercise, (right) The 3D puzzle exercise

The evaluation both pre and post-therapy was carried out with both clinical and quantitative (EMG, motion data) measurements, the latter ones measured in terms of different kinetic parameters estimated through the online data logged during the repeated sessions of exercise. Significant improvements were found both in clinical scales, such as Fugl-Meyer score (paired t-Student test, p < 0.003), active and passive ranges of motion, and quantitative indexes, such as task time and error, synergies and smoothness of movement.

![Figure 4](Example of improvement in time of execution of exercise 2 over therapy sessions)

The paper will present the details about the protocol and achieved results, with an overview also of an extension of the rehabilitation exercise to the rehabilitation of children with central paralysis. In particular two further exercises will be described: a modified version of the constraint circular motion (with unwarping of a given image) and a cleaning task with a virtual sponge.
Figure 5 Applications developed for the rehabilitation of children. (left) Constrained circular motion unwarps a target image. (right) The virtual cleaning sponge