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AN ACTIVE ARM SUPPORT FOR WHEELCHAIR

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SUMMARY

An active system for enhancing impaired upper limb mobility and to generate therapeutic training exercises has been developed at the Department of Mechanics of Politecnico di Milano. In recent years several active robots have been marketed for applications in this field but they are mainly for clinical environment while there is a lack of devices suitable for home use. The robotic system here described has a simple kinematic structure and since it is aimed at the home user, it is a portable device and is suitable to equip a wheelchair.
The robot has several working modes and can be used with the purpose of providing assistance to the movement of the arm or to the execution of rehabilitative exercises.

INTRODUCTION

The numbers of people - post-stroke, road injured and affected by other kinds of motor disabilities - who require help for daily living activity are increasing. In Italy [1], for instance, 30 % of stroke patients is seriously lacking in the activity of daily living (ADL).
Therefore the development of an effective robotic device to improve their quality of life is essential.
The mechanical devices which can be used to help the patients in the ADL can be active or passive, that is whether motorized or not. They may also be classified as exoskeletons or end-effector robots where the first definition indicates the systems connected in parallel to each segment of the kinematic chain of the arm and the second indicates systems connected to the arm only in one point: the first choice has a critical need of precision in the connection of the device to the patient in order not to overstress the arm joints. Moreover they can be divided into home and hospital devices [2, 3].

METHODS

Purpose of the present research is the development of a home device as simple and light as possible thus it has an end-effector architecture and is equipped by little and light motors and transmissions. The electronics of the system have been appositely designed and produced, and the boards communicate by the I2C protocol which requires only two wires.
The device can be connected to the frame of a wheelchair on a fixed point slightly behind and besides the patient shoulder and supports the forearm of the subject(Fig.1).
Three of the five degrees of freedom of the mechanism are active and equipped by brushless motors while two are passive. The system allows the free forearm prono-supination.
The resulting working volume of the arm includes most of the positions required for ADL (Fig.2).
In order to reduce size and weight of the motors as well as the energy consumption a set of springs, cables and pulleys are used for total or partial weight compensation of both the device and the human arm.

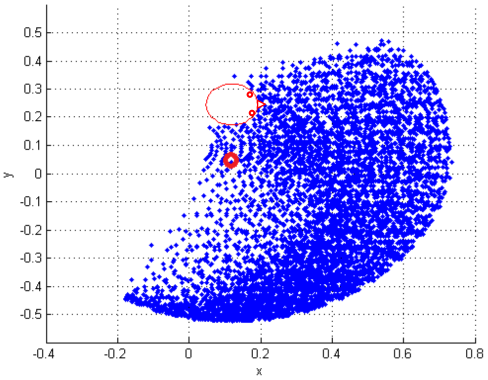
Figure 1: the new device mounted on a wheelchair during a test of the first operating mode.

RESULTS AND DISCUSSION

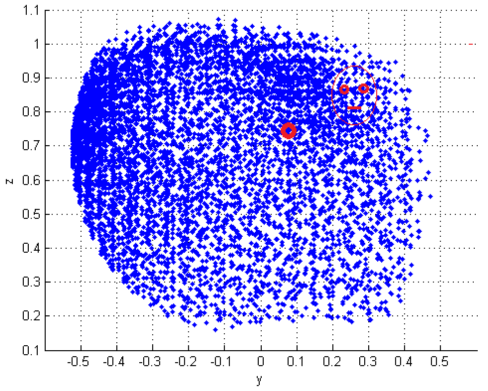
The robot has different operating modes.
When the arm of the subject is completely passive, the device (in the first operating mode) must provide the patient of the full help - energy and control - required for a pre-settled movement.

As the subject's condition improves it is possible to use another operative mode with which the machine help can be modulated to the patient ability: this approach allows to monitor and certify the improvements. When a patient is enough strong the robot can also work against the subject action in order to strengthen the muscles. With another operating mode the subject can be partially or totally released by the gravity forces, so that a weak arm can recover the active ability to move the limb. For patients with a great control deficiency, the machine can also act only constraining the hand to move freely on a pre-settled trajectory.

The last working mode of the system, the more complex and still under development, will provide the patient of the help to perform a generic, not previously known task. This function will probably be the most effective for the ADL. The challenging part of this development is the decoding of the patient will of motion.



(a)



(b)

Figure 2: working space of human arm in presence of the assistive device: (a) top view, (b) front view where red circles show the position of head and shoulder joint.

The control of the system is based on the mechanical impedance control technique. The aim of this approach is to find desired dynamical relations between external force on end-effector and motion of the robot. This control is particularly useful for the active working modes of the device where the impedance parameters are adjusted according to patient's needs of help from the machine.

The final input torque of the motors can be written in the following simple form [4]:

$$\tau = J_R^T(q)(K_d(x_d - x) + D_d(\dot{x}_d - \dot{x})) + g_R(q) - \tau_{spring}(q)$$

where:

- $J_R(q)$ is robot jacobian
- x_d and $\dot{x}_d$ are position and velocity of the hand
- K_d and D_d are impedance parameters
- $g_R(q)$ is gravity torque
- $\tau_{spring}(q)$ is torque provided by springs

CONCLUSIONS

The very preliminary tests of the prototype of the new device mounted on a power wheelchair are encouraging: it is light, not too noisy, and easy to move by the subject. The first mode - full gravity compensation - and the second working mode of the device have been implemented and are under patients tests, as well as the mode with which the subject is helped to repeat a stereotyped exercise for auto-physiotherapy. For these initial tasks the system seems to be user-friendly but the control system must by calibrated on patient characteristics.

The current major research effort, in close contact with the patients, concerns the set up of the other working modes in which the system must interpret the patient's will of movement. The adequacy of the solution is strictly related to the kind of disability considered.

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