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Control design of a 2 DOF hand exoskeleton for cylindrical grip movement rehabilitation

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***Abstract*—In this paper, it's presented a trajectory tracking control by using PD Computed Torque Control (PD CTC) strategy for a nonlinear two-link robotic hand exoskeleton. The control strategy performance analysis was carried out through simulations in MATLAB/SIMULINK. Good performance and a very small error was obtained.**

***Keywords*—nonlinear system, control algorithm, PD Computed Torque Control.**

I. Introduction

Cylindrical grip exercises are helpful for improving motor skills in rehabilitation therapy after a neurological event like stroke or brain injury. This paper aims to perform an assisted therapy by using a hand exoskeleton. It must steer cylindrical grip movements by using a PD Computed Torque Control. The error between the desired and the actual trajectory of the exoskeleton is significantly reduced.

II. Controller Design

Exoskeletons fingers can be modeled as a planar manipulator with 2 degrees of freedom [1]. Since traditional control system do not provide a good performance, a non-linear dynamical model of the proposed exoskeleton based on non linear equations was obtained.
Given by:

$$D(q)\,\ddot{q} + C(q,\dot{q})\,\dot{q} + g(q) + F(\dot{q}) = \tau \quad (1)$$

Then, the equations for dynamics of robotic hand exoskeleton with rigid link, is mathematically written by [2]:

$$D(q)\,\ddot{q} + N(q,\dot{q}) = \tau \quad (2)$$

$$N(q,\dot{q}) = C(q,\dot{q})\,\dot{q} + G(q) + F(\dot{q}) \quad (3)$$

Finally, the proposed control law remains as shown below:

$$u = D(q)\left(\ddot{q}_d + K_v\dot{e} + K_p e\right) + N(q,\dot{q}) \quad (4)$$

where $e(t)$ is the tracking error, whose equation is:

$$e(t) = q_d(t) - q(t) \quad (5)$$

with $q_d(t)$ desired joint angle and $q(t)$ is the real joint angle.

In Fig. 1. it is shown the Simulink design for the control algorithm. For this simulation, the plant was exported from SolidWorks by using Simscape Multibody.

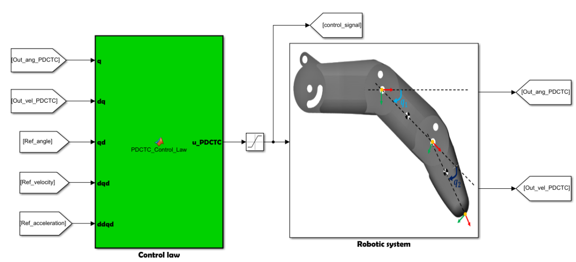

Fig. 1. Control structure for the computed torque controller type PD.

III. Results

Based on the design parameters obtained in Tab. I for the control algorithm, the exoskeleton system follows the trajectory with good performance obtaining a maximum error of $5.95x10^-5$ for both joints as shown in Fig. 2

TABLE I
Design Parameters.

Joint(i)	$Kv_{(i)}$	$Kp_{(i)}$
1	90	65000
2	190	77000

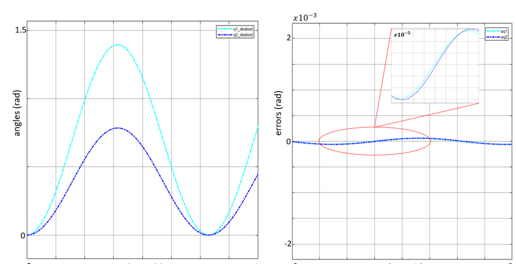

Fig. 2. Left-reference angles (in rad), Right-errors for each joint (in rad).

IV. Discussion and Conclusions

The control design applied to the hand exoskeleton allows it to follow a certain trajectory with high accuracy. Further research may include specific trajectories and controllers.

References

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[2] C. C. de Wit, B. Siciliano, and G. Bastin, *Theory of robot control*. Springer Science & Business Media, 2012.