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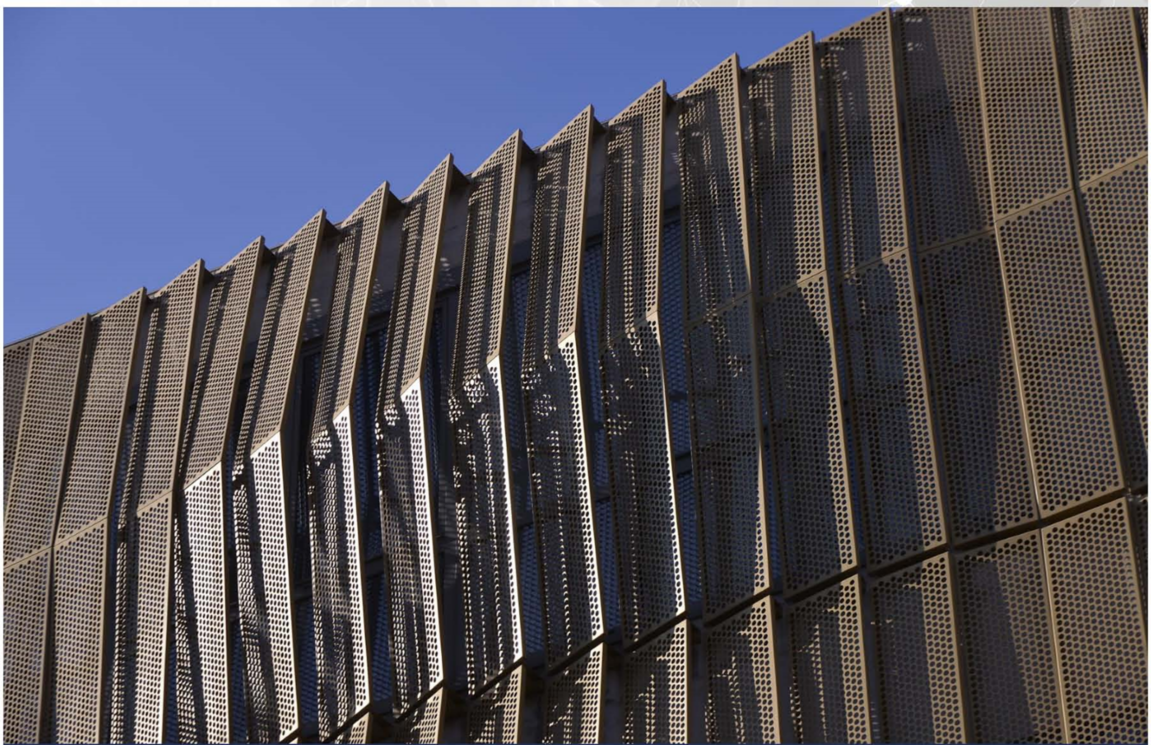

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Issues in the mechatronics design of a full arm rehabilitation device

T. Arrigoni,[1, 2, *] S. Zelenika,[1, 2] E. Kamenar,[1, 2] T. Schnurrer Luke Vrbanić[3] and K. Lenac[1]

[1] *University of Rijeka, Faculty of Engineering, Vukovarska 58, 51000 Rijeka, CROATIA*
[2] *University of Rijeka, CMNST, Radmile Matejčić 2, Rijeka, CROATIA*
[3] *U. of Rijeka, School of Medicine, Braće Branchetta 20, 51000 Rijeka, CROATIA*
E-mail: tea.arrigoni@gmail.com, sasa.zelenika@riteh.hr

1 Introduction

Stroke is the leading cause of adult disability in western countries. Impairments in movements are among the most common consequences of stroke, while upper limb functions are altered in up to 75 % of the patients [1]. Traditional therapy for the recovery of patients with arm impairments involves physical therapists that control the movements and help the patients recover the motion ability. The limited number of physiotherapists and of their time availability constitute here an increasing problem. In the last decades, robotic-based rehabilitation devices have thus become common. These can have a varying number and arrangement of DOFs that influence the ease of movement but also the size, weight and price of the device [2]. The aim of this work is, hence, to perform an initial evaluation of the issues in the mechatronics design of a full arm rehabilitation device in order to find an optimal and highly efficient solution at a reasonable cost.

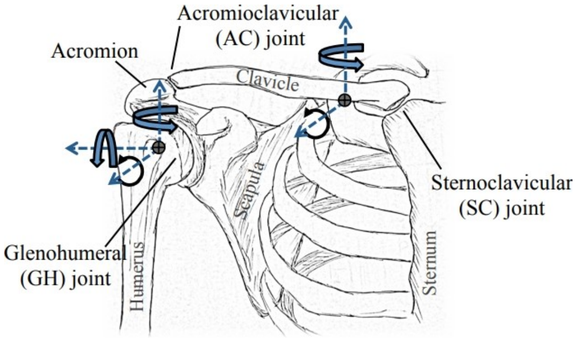

Fig. 1. Human arm [3]

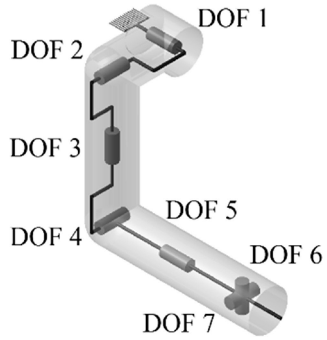

Fig. 2. The 7 DOFs model of the arm

2 Human Arm Behaviour and Respective Mechatronics Components

A crucial task in designing an arm rehabilitation device is the study of the arm's movement kinematics (Fig. 1). The human arm and the respective rehabilitation device are commonly modelled in literature as a 5-7 (and even up to 11) DOFs system [2]. Analysing then in depth the rehabilitation devices currently available on the market, it is concluded that the 7 DOFs models provide a good combination of motion accuracy with an acceptable model complexity (Fig. 2); this configuration is thus chosen for the design of the herein considered active rehabilitation device. The active part of this device is whence considered as a system with several sets of the three main hardware components,

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[*] Corresponding author

i.e., the actuators, the sensors and the control unit. In fact, the actuators should provide the needed help to the patients while performing the motions otherwise not achievable by their own, while the sensors should provide the needed feedback to the used control system so as the optimize the level of help when the patients' autonomy level is reached.

The commonly used types of actuators used in arm rehabilitation devices and their main characteristics are evaluated in Tab. 1. It is to be noted here that DC and servomotors use electricity and thus generate heat, whereas pneumatic motors make a lot of noise. Hydraulic motors are quiet but they and the pneumatic motors can generate problems related to leakages and often require a lot of space. On the other hand, the most commonly used sensors in arm rehabilitation devices and their features are listed in Tab. 2. Clearly, the position sensors should be of the absolute type so as to be ready at power up.

Tab. 1. Actuators and their main characteristics

	Pneumatic	Hydraulic	Servomotor	DC motor	Muscle (hydraulic)
Power	Middle	Very high	Low	Middle	High
Velocity	High	High	High	Low	High
Flexibility	High	Middle	High	Low	High
Price	Low	High	Very high	High	Middle
Efficiency	Low	Middle	High	High	Low

Tab. 2. Sensor types and their characteristics

	MEMS inertial	Magnetic angular	Capacitive	Torque	Pressure & touch	Electro-myography
Measurement type	Displ., direction, orient.	Joints' angles	Force	Joints' torque	Pressure	Muscle activation
Dimensions	↓↓	↓	↓↓ … ↑↑	↑	↓	↓
Price	High	Low	High	Middle	Middle	Middle

3 Conclusions and Outlook

Considerations about the number and arrangement of DOFs and of the usable actuators and sensors complement the performed initial critical evaluation of the configuration to be adopted in designing the mechanics of an efficient full arm rehabilitation device at a reasonable cost. Obviously, a proper choice of the other components (power supply, gearheads and similar) should also be performed bearing in mind the overall weight and needed floor space of the overall device. The configuration of the respective computing part controlling the performances of the complete mechatronics device, complemented ideally with a virtual reality users' interface that allows following patients' improvements and stimulating them to make full use of their efforts, will allow completing the layout of the considered device. It should finally provide the rehabilitation treatment with high intensity and frequency and support the rehabilitation of both the left and the right arm.

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