Modeling and simulation of a parallel mechanical elbow with 3 DOF

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Abstract

The modeling and simulation of a mechanical elbow of 3 degrees of freedom, is introduced by highlighting the main features of the mechanism related to the design criteria. The mechanical elbow is used as a transhumeral prosthetic part, and it has been built as a parallel topology consisting of electric linear actuators and universal joints. The parallel mechanism has 4 legs: 3 made with electric linear actuators, and the fourth leg provides mechanical support for the whole structure and holds a DC Motor that performs the action of gripping objects. Furthermore, this paper shows the inverse kinematics for the elbow by geometric methods, and the MatLab-simulation results show the workspace of the movement and the ability of the mechanical elbow to replicate the movements of a biological one.

1. Introduction

Current research in prosthetics have been focused on the development of prosthetic hands and prosthetic legs [1]-[2]. However, the research and development of elbows is very poor and current research has been focused only to prosthetic elbows with one degree of freedom (DOF). In the same manner, both mechanical and myoelectric prosthetic elbows [3] are serial and with a single DOF, such as: Utah Arm [4], and the Edinburgh Arm [5]. An improved development is a serial mechanism with 3 DOF [6], but with the disadvantage that it is not suitable for high weights and its electronic devices are not portable so that it cannot be used in prosthetic elbows. Similar developments with pneumatic muscles present this problem [7]. In contrast, a complete and functional prosthetic elbow must have 3 motorized-axes in order to provide 3 DOF [8]-[9], namely: flexion-extension, pronation-supination and humeral rotation, as shown in Fig. 1 [10]. These movements can be defined with major axes according to [11]-[12], and this capacity lets us to evaluate the movements required for a prosthetic elbow, which should perform the movements of a biological one.

In [13]-[14] is introduced a new motorized design of a prosthetic elbow performing flexion-extension, pronation-supination, and humeral rotation, with the characteristic of having electrical drives actuators in a parallel topology, as shown in Fig. 2. Its main advantage is that it provides an improved workspace higher than typical parallel robots, due to the mechanical configuration and universal joints. Most important is that the link of the mechanical elbow supports high loads and allows a workspace fitness for a prosthetic hand with 3 DOF. Henceforth, in this paper is introduced a general description on the modeling and simulation of the prosthesis and its ability to emulate human elbow movements.

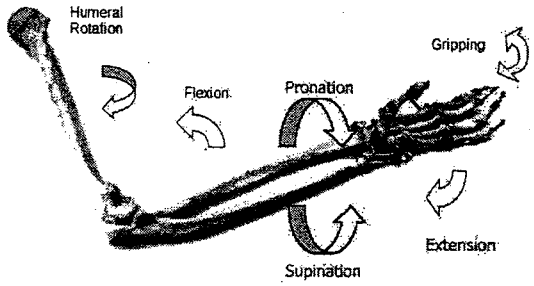

Fig. 1. Movements of a human elbow: flexion-extension, pronation- supination, and humeral rotation.

2. Elbow prosthesis mechanism.

2.1. Design basics

There are different types of actuators [15]-[16], but we have found that among electrical actuators have the best characteristics: small size, low weight, low power consumption, high torque, the best power/volume ratio silent operation, minimal heat generation, fast response and simple control.

The important part in the selection of an actuator is related to give to the prosthesis enough space to contain the electrical and electronic components. In this work, we used DC brushless motor to have better power/volume and power/weight ratio than brushed or induction motors. The mechanical design of the elbow was developed in Solid Edge, exploiting its ability to make dynamic simulation

For instance, the basic concepts involved in the modeling and simulation of the parallel mechanical elbow of 3 DOF are:

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