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Kinematic Modelling and Task-Based Synthesis of a Passive Architecture for an Upper Limb Rehabilitation Exoskeleton

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Abstract : An exoskeleton design for rehabilitation purpose encounters many challenges, including ergonomically acceptable wearing technology, architectural design human-motion compatibility, actuation type, human-robot interaction, etc. In this paper, a passive architecture for upper limb exoskeleton is proposed for assisting in rehabilitation tasks. Kinematic modelling is detailed for task-based kinematic synthesis of the wearable exoskeleton for self-feeding tasks. The exoskeleton architecture possesses expansion and torsional springs which are able to store and redistribute energy over the human arm joints. The elastic characteristics of the springs have been optimized to minimize the mechanical work of the human arm joints. The concept of hybrid combination of a 4-bar parallelogram linkage and a serial linkage were chosen, where the 4-bar parallelogram linkage with expansion spring acts as a rigid structure which is used to provide the rotational degree-of-freedom (DOF) required for lowering and raising of the arm. The single linkage with torsional spring allows for the rotational DOF required for elbow movement. The focus of the paper is kinematic modelling, analysis and task-based synthesis framework for the proposed architecture, keeping in considerations the essential tasks of self-feeding and self-exercising during rehabilitation of partially healthy person. Rehabilitation of primary functional movements (activities of daily life, i.e., ADL) is routine activities that people tend to every day such as cleaning, dressing, feeding. We are focusing on the feeding process to make people independent in respect of the feeding tasks. The tasks are focused to post-surgery patients under rehabilitation with less than 40% weakness. The challenges addressed in work are ensuring to emulate the natural movement of the human arm. Human motion data is extracted through motion-sensors for targeted tasks of feeding and specific exercises. Task-based synthesis procedure framework will be discussed for the proposed architecture. The results include the simulation of the architectural concept for tracking the human-arm movements while displaying the kinematic and static study parameters for standard human weight. D-H parameters are used for kinematic modelling of the hybrid-mechanism, and the model is used while performing task-based optimal synthesis utilizing evolutionary algorithm.

Keywords : passive mechanism, task-based synthesis, emulating human-motion, exoskeleton
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