HandExos: a Modular Wearable Device for Hand Rehabilitation

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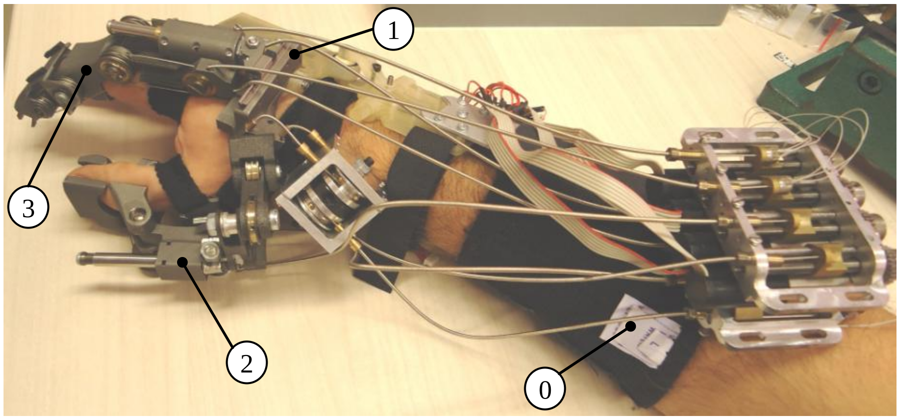

Figure 1: HE device. The 4 modules are presented with different indexes. 0-forearm: overall fixed frame plus a the passive elements that allow abd/adduction and flex/extension of the wrist. 1-hand back: reference frame for the finger modules. 2-thumb: abd/adduction is independently actuated, achieving thumb opposition, while phalanges flex/extension is underactuated by a single motor. 3-index: two motors under-actuate flex/extension of the three phalanges, abd/adduction is passive. Actuation block and Bowden hoses are clearly visible: for details of the hand-interface part, refer to attached video.

I. Introduction

POWERED exoskeletons gained increasing relevance in the field of rehabilitation robotics during the last years. These robots can be exploited to control the movements of patients having neuro-muscular impairment, following, e.g., stroke, spinal cord injuries (SCI), or cerebral palsy [1], to restore their lost functionalities [2]. Compared to end-point external machines, exoskeletons present the advantage of independently controlling each degree of mobility of the user's limb, thanks to the specific interaction between the robot links and the user's body segments.

This theoretical advantage is however hardly achieved by the real system performances, due to several issues, mainly related to design of the physical human-robot interface (pHRI). In fact, the pHRI design has to merge human-oriented requirements, such as inherent safety, adaptability to anthropometry variability, and wearing easiness, with an effective bi-directional transfer of torque.

In recent years, several applications for hand or fingers rehabilitation have been presented [3]. In this work, we present HandExos (HE, Figure 1), a novel wearable active device, which mechanical and kinematic pHRI design tries to satisfy the requirements presented above.

II. Materials and Methods

In order to be effective, a basic requirement for an exoskeleton is to be *wearable*. To provide an easier wearing procedure, HE has been designed following a modular approach: 4 modules (i.e. forearm and wrist, hand back, index finger and thumb) compose the exoskeleton, and are mounted and fastened to the user in sequence (see the attached demo-video). Each HE module is attached to a dedicated actuation unit through flexible Bowden-cable hoses, which do not impair the donning and slightly affect the torque transmission.

Between each module, different degrees of freedom (DoFs) are provided. The kinematical architecture of the its active and passive DoFs endows the HE with the capability of controlling the main human hand degrees of mobility (see Figure 1), with *self-aligning* properties. The transmission system encompasses cable-driven idle pulleys, whose layouts have been studied in such a way that it can directly control the rotations between the hand segments, and comply passively with the relative positions of the rotation centers of such segments. In this way, HE can adapt to the hand anthropometry variability and to deviations from the kinematic model.

III. Conclusions

HE achieves a high wearability and a high human hand kinematic compatibility, through a wrist-hand-fingers modular approach, exploiting passive DoFs and a remote under-actuation system. HE conjugates compliance to human kinematic variability, and an effective actuation system. It has light mass (1 kilo, of which 300 grams of actuators) and low encumbrance (it maintains the palm free, for an effective grasping rehabilitation). It can provide relatively high bi-directional torques (450 mNm peak for each actuator) and, very importantly, it is the first platform providing a three-dimensional thumb motion.

References

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