Chapter 17
The "Arm" Line of Devices for Neurological Rehabilitation

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ABSTRACT

In the modern scenario of neurological rehabilitation, which requires affordable solutions oriented toward promoting home training, the Institute of Industrial Technologies and Automation (ITIA) of the Italian National Research Council (CNR) developed a line of prototypal devices for the rehabilitation of the upper limb, called "Arm." Arm devices were conceived to promote rehabilitation at affordable prices by capturing all the main features of the state-of-the-art devices. In fact, Arm devices focus on the main features requested by a robot therapist: mechanical adaptation to the patient, ranging from passive motion to high transparency, assist-as-needed and resistive modalities; proper use of sensors for performance monitoring; easy-to-use, modular, and adaptable design. These desirable features are combined with low-cost, additive manufacturing procedures, with the purpose of meeting the requirements coming from research on neuro-motor rehabilitation and motor control and coupling them with the recent breakthrough innovations in design and manufacturing.

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INTRODUCTION

The use of robotic devices for upper-limb neuro-motor rehabilitation is usual practice in clinical centers. In respect to conventional therapies, robots allow to increase training intensity and help patients to promote their active contribution. Furthermore, robots can act as measurers of patients' performances and adapt their interaction modalities to the emerging needs during the rehabilitation course. Robots like ARMin, MIT Manus, Armeo Spring, Braccio di Ferro, represent the state of the art devices for rehabilitation of the upper-limb and for promoting motor recovery. According to the available assessments and studies in the literature, their efficacy is slightly/moderately higher than the one of conventional therapies. Furthermore, robots are used in research to learn more about physiological and pathological motor control and neuromuscular diseases. Unfortunately, while being the state of the art devices for neuro-motor stimulation and training, such robots are very expensive and not compliant to user-friendly requirements that are needed for semi-autonomous home use. Consequently, they can be used only in clinical environments, under the supervision of medical personnel. Furthermore, sanitary costs related to rehabilitation are increasing and clinical centers can hardly support their burden. The possibility of delocalizing rehabilitation from clinical centers opens the chance for training performed in home environment, with time and costs savings for both the sanitary system and patients. In this scenario, which requires affordable solutions oriented toward promoting home training, the Institute of Industrial Technologies and Automation (ITIA) of the Italian National Research Council (CNR) developed a line of prototypal devices for the rehabilitation of the upper-limb, called *-Arm*. *Arm* devices were conceived to test the possibility of promoting rehabilitation at affordable prices but capturing all the main features of the state of the art devices. In fact, *Arm* devices focus on the main features requested by a robot therapist: mechanical adaptation to the patient, ranging from passive motion to high transparency, assist-as-needed and resistive modalities; proper use of sensors for performance monitoring; easy-to-use, modular and adaptable design. These desirable features are combined with low-cost, additive manufacturing procedures, with the purpose of meeting the requirements coming from research on neuro-motor rehabilitation and motor control and coupling them with the recent breakthrough innovations in design and manufacturing. *Arm* devices cover both clinical and home-oriented training and are designed for adaptation to patients with different motor impairment.

The *Arm* prototypes are:

- **LINarm**: linear device, freely orientable in space, suitable for functional movements. It features a variable stiffness actuation, allowing to adapt the mechanical behavior of the device to patients' needs. Functional Electrical Stimulation, simple Virtual Environments and a Patient Model, gathering data from integrated sensors and modulating the level of assistance, are integrated in the set-up. The LINarm++ Echord++ Project ended in October 2016 and guided the development of a second, more refined prototype, enhancing the original concept.
- **PLANarm**: planar device, freely orientable in space, suitable for planar functional movements. The state of the art planar robots used in literature for motor control and motor learning research inspired PLANarm. It features a variable stiffness actuation, allowing adapting the mechanical behavior of the device depending on patients' needs.
- **DUALarm**: Low-Cost device for bimanual rehabilitation, exploiting the capability of the less affected limb to provide rehabilitation to the more affected limb. DUALarm is completely realized in 3D printing technology and aims at being an easy-to-use, low-cost, open-source project.

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