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# Driving device for a hand movement without external force

Esteban Peña-Pitarch*, Neus Ticó Falguera, Joan Antoni Lopez Martinez, Anas Al Omar, Iñaki Alcelay Larrión

*Escola Politècnica Superior d'Enginyeria de Manresa (UPC), Av. Bases de Manresa, 61-73, (08240) Manresa, Spain*

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ABSTRACT

People with disabilities have limitations in activities of daily life such as grasping a glass of water or moving an object. Orthotic products that improve or restore the functionality of the musculoskeletal system of a patient contribute to some extent to overcome the limitations described. So does the hand brace, used to treat musculoskeletal disorders caused by various diseases (rheumatic disorders, neurological, orthopedic and others). The paper simulates a novel exoskeleton helping to grasp any object. The novelty of this mechanism is that works without external energy, it works with a wrist movement that generates a kinetic movement and helps to grasp objects with an extra force. The orthosis facilitates the functionality, being comfortable and easy to be used by the patient. It is adaptable to hand size and finger length of the patient.



## 1. Introduction

Hand partial disabilities become a serious problem for many people, who neither have mobility and feeling in their hands, nor enough strength to support objects such as a simple glass of water. Mainly elderly people suffer this problem, but also many people who have suffered accidents and people with certain types of musculoskeletal conditions such as osteoarthritis.

However, the technology developed has the novelty of being comfortable and easy to be used by the patient. It is adaptable to hand size and finger length of the patient and needs no power source for operation.

For several decades the development of a new hand brace has included new technological advances. However, there is still a significant gap between the state of the art equipment designed in terms of presenting a combination of highly functional, durable, aesthetically and economically viable [5]. In this regard, a number of factors are critical in the design of actuators for a hand.

In principle the design of the device used will be taken into account and therefore the device will be adapted to the size of the patient's hand and will have a suitable weight so that it can be used comfortably.

Furthermore the design must consider what is the best operating mechanism of the device in terms of type of actuator (manual or electric), the gripping force provided by the apparatus and the gripping speed thereof. Finally, the design will have to evaluate which method is the union of the joints and the type of grip that provides special emphasis on the thumb because it is responsible for 40% of full functionality of ones hand [16]. In this sense, the technology developed in this paper takes

* Corresponding author.
*E-mail address:* esteban.pena@upc.edu (E. Peña-Pitarch).

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into account the following: It can be adapted to different hand sizes of patients and amplifies grip strength in addition to not requiring any external power source (no batteries or batteries, or Electromyography (EMG)) and is driven only by the flick of the wrist. Therefore, the technology developed can be easily and conveniently used by patients when performing daily activities. It is easy to manufacture and it is economically competitive since it does not require complex mechanical components, which can make the technology developed one of the key factors when it comes to be funded by the National Health Service (NHS).

There are a variety of devices for a hand operation that enable or facilitate the movement or function of it. Orthosis is an orthopedic appliance or apparatus used to support, align, prevent, or correct deformities or to improve the function of movable parts of the body. Based on this definition, our research is focused on the development, design, and building of an exoskeleton, so named our orthosis. This device needs to follow four initial premises: a) all the components could be built by the users, b) could be used without any external forces, c) aesthetic appearance and ergonomic aspect, and d) the target people to used it are those with little hand mobility and without force, such as elderly or people who suffer from some pathologies.

Under these premises we design and build an exoskeleton that works with a wrist movement and helps to grasp any object used in the active daily live (ADL). We consider two types of grasp: power grasp, when grasp using the palm, and precision grasp when grasp using the fingertips, defined in [18].

One model of an orthotic hand that has been investigated consists on an exoskeleton with four degrees of freedom for the rehabilitation of the index finger. The device can generate bidirectional motion (flexion-extension) for all joints of the finger and it is adjustable for various hand sizes. Force sensors such as FlexiForce and encoders with a DC motor are used to measure the angular position. The information received from the sensors is used to control the exoskeleton and to evaluate and analyze the effects of rehabilitation [19]. One more anthropomorphic hand was presented. The problem with this design is that comprises a DC motor since it uses a power source; therefore, the exoskeleton does not have a prolonged time of use [1].

Another orthotic model studied was an exoskeleton for hand rehabilitation [20], a mechanical prototype with four degrees of freedom, which is moved by an actuating unit and receives information through the Hall effect sensors in each joint structure. This model can also use resistive force sensors at the top and bottom of the phalanges and myoelectric sensors to measure the activity of some muscles of interest. The problem with this type of hand brace lies not only in the need for an external power source but can also pose a greater weight to the patient's hand where it is applied.

An orthotic hand for preventive purposes was also designed [14]. In this sense, it highlights a prototype exoskeleton designed to fit into the gloved hand of an astronaut and to counteract the rigidity of the pressurized space suit. The hand movements are monitored with an array of pressure sensors located between the exoskeleton and the hand. By means of a micro-controller, the commands apply to a driver under Pulse With Modulation (PWM) controlled motor.

Finally, other prototypes were designed in order to create virtual environments with which to interact. In this area, some authors have proposed a new methodology for master-slave systems, using passive force feedback [5] to build an exoskeleton master hand with three fingers and four degrees of freedom (DOF) each, using force feedback and a control algorithm that uses electromagnetic clutches and elastic elements. Its operation is based on a switch between force control and position control, and this switching depends directly on whether it is in contact with an object. With the exoskeleton built and implemented control strategy we can design a virtual reality system for the hand. In the same direction, an exoskeleton proposed by other authors allows full extension and flexion of the fingers and thumb [16]. Some of them apply a two-way feedback, and others, three DOF for the index and four DOF for the thumb. They use direct current motors, power cables and force sensors to measure the power of the actuators and the ability to force one's hand. The facility is designed to be used in conjunction with a commercial haptic arm with six DOF, in order to enable simulation of external forces.

A technique to stimulate finger pad shear deformation transferred to the side of the fingertip was developed by [6]. However, Nakatani et al. [8] developed a wearable sensor system for estimating finger contact force by measuring the mechanical deformation of the side of the finger pad. A new model to simulate contact and rolling motion between two soft fingers and an object by using Finite Element Method (FEM) and constraint stabilization methods. In similar line Ref. [9] presents a hemisphere-shaped soft finger for soft fingers, based on force distribution.

Pressure distribution on the hand surface during hand grasping an elliptic cylindrical handle was study by [17] based on computer aided engineering analysis. Wu et al. [21] presented a study intended to analyze, theoretically, the time dependent deformation profile of skin surface, the strain distributions within soft tissue, and the response force of a fingertip when it is stimulated by a probe vibrating with a sinusoidal movement. In order to simulate the skin contact deformation mechanism, a physical model based on the Boussinesq approximation with nonlinear elasticity and a compressing-swelling effect was proposed by [22].

Shields et al. [13] showed a complete grasp model used to simulate an experiment in which a subject was asked to grasp two cylinders of different diameters and weights. It showed similar angles in the experiments to the ones that we calculate with our approximation. Similar results are also shown when using objects with 3, 5, or 7 cm in diameter in [3]. Using an instrumented cylinder Ref. [4] described the magnitude of pinch force as the function of a cylinder allowing simultaneous measurements of the opposition axis of the index and the thumb of the hand. Boc et al. [2] have introduced a paradigm in which subjects grasp from the same starting position to the same final object, once as a typical laboratory task and once as a part of everyday-like behavior.

This paper is organized as follows: Section 2 shows the device. Section 3 introduces results and discussion. Finally conclusions are given in Section 4.