Design of a prototype of hand orthosis with pneumatic actuators

Diseño de un prototipo de órtesis para mano con actuadores neumáticos

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Keywords

Orthosis; pneumatic actuation; cerebral palsy; soft robotics.

Abstract

In Costa Rica, there has been an increasing need for prosthetic and orthotic devices in the last years, especially in populations with diabetes, cerebral palsy, and people over 65 years old, some of the devices are developed in the country, however, others such as hand orthoses are rarely produced in the region. The use of soft robotics in the replica of human movement has been growing. By considering the work done by Deimel and Brock[3] and the Simulation Bioengineering Laboratory(SIBILA) it is intended to develop a soft hand orthosis for a patient with cerebral palsy, who has problems grasping objects with his right hand. This project aims to improve grip strength and finger position for the patient. The project is divided in 3 parts: replica of the patient's hand, elaboration of pneumatic muscles and the elaboration of a voice control system. The result is a pneumatic actuation that allows to grip objects with different shapes and gives strength to the fingers, in addition to this, the orthosis fits the model of the patient's hand. In conclusion, it is recommended to optimize the design of the muscles with a silicone that is more resistant and a thicker reinforcement helix. Also, it is recommended to start carrying out the tests of the orthosis with the model of the hand inside it.

Palabras clave

Órtesis; actuación neumática; parálisis cerebral; robótica suave.

Resumen

En Costa Rica, en los últimos años se registró un aumento en la necesidad de dispositivos protésicos y ortésicos, en poblaciones con diabetes, parálisis cerebral y adulta mayor, algunos de los dispositivos son elaborados en el país, sin embargo, otros como las ortesis de mano son raramente producidos en la región. El uso de robótica suave en la réplica del movimiento humano ha venido en crecimiento,por lo que tomando en cuenta lo desarrollado por Deimel and Brock[3] y en el Laboratorio de Simulación y Bioingeniería(SIBILA) se pretende crear una órtesis de mano con robótica suave para un paciente con parálisis cerebral, el cual tiene problemas para asir objetos con su mano derecha. Se busca mejorar la fuerza de agarre y la posición de los dedos. El proyecto se divide en 3 partes: desarrollo de una réplica de la mano del paciente, elaboración de los músculos neumáticos y elaboración de un sistema de control por voz. El resultado es una órtesis de actuación neumática que permite asir objetos de distintas formas y brinda fuerza a los dedos, además la órtesis se ajusta al modelo de la mano del paciente. Se recomienda utilizar un silicon e hilo más resistente, además de realizar pruebas con el guante colocado sobre la réplica de la mano.

Introduction

In Costa Rica, there has been an increasing need for prosthetic and orthotic devices in the last years. In 2017 the CCSS (Caja Costarricense de Seguro Social) received 2254 request for prostheses and made 890 of these, this need has increased 2.7 times in the last 6 years [2]. The need of orthotic devices is also expected to grow in the coming years. For example, current research establishes that up to 74% of stroke patients need of long-term assistance [8]. 75% of patients with stroke are people over 65 years old, a population that has been growing at an accelerated rate the last few years. In Costa Rica in 2015, 7.36% of the population was

composed of people over 65 years old [6], and it is expected to triple by 2040 [5]. This population is expected to keep growing in the following years which means an increase in prospective users of orthotic devices. This, devices are however rarely made in Costa Rica (in the case of hand orthosis). Other populations that are prospective users of these devices are the people with cerebral palsy and diabetic people. In 2017, around 9.6% of the population older than 20 years old in Costa Rica had diabetes, this percentage is expected to grow to around 12.6% in 2045 [4]. 40% of these patients tend to have problems with their hand movements [7].

The use of soft robotics has been growing as a medium for replicating natural movements. For example, Deimel and Brock[3] have developed a soft actuated hand that is able to grasp successfully objects with different shapes. At the Simulation Bioengineering Laboratory (SIBILA) 2 previous attempts have been made to develop a soft orthosis. Of this 2, an interesting first approach was made by Arrieta[1] who made an initial attempt to develop a soft orthosis actuated with pneumatic muscles. In the current project, we attempt to use the pneumatic muscle design made by Deimel and Brock[3] to develop a soft hand orthosis, taking into account the results of the 2 previous iterations done at the laboratory.

This project in particular was developed for a patient with cerebral palsy. This patient has problems grasping objects with his right hand, this is because he has difficulty holding his fingers in the adequate position. As a means to help him, it is born the idea of designing an orthosis that is able to provide his fingers with support by increasing the strength with which the patient is able to grab objects as well as helping him maintain the position of his fingers.

Materials and Methods

For the elaboration of this project is needed the following materials:

- Epoxy resin
- Torsion springs
- Silicone: Dragon Skin FX-Pro®
- Polyester thread
- Polyester fabric
- Raspberry PI 3B+
- Sensors: Force Sensitive Resistors.
- USB Microphone

The elaboration of this project can be separated in 3 different parts:

First of all, a replica of the patient's hand was made using epoxy resin in order to be able to verify that the orthosis complies with the geometry of the hand of the patient. This model is articulated with torsion springs and it is able to flex to the same angles that the patient uses for grabbing objects. Said replica can be seen in figure 1.

The second part was the elaboration of the actuators used to mobilize the fingers of the patient. This actuators need to be made of a soft material that can be in contact with skin. Said material also has to be able to provide the necessary strength for the orthosis and have a good lifespan. This is why it was decided to use pneumatic muscles that are made of silicone. This material plus the design applied to the muscles allow them be soft to the contact with skin as well as having the necessary rigidity to hold down the fingers of the patient. This muscles are made by using molds and a cape of silicone spread over polyester screen. Once the muscles have hardened, a reinforcement helix made of sewing thread is wrapped around them, this allows the

muscles to have the appropriate movement. The muscles are inflated using a 12V air pump. The silicone used for the design of the muscles was Dragon Skin FX-Pro®. Other types of silicone were also tested. The model used for the design of this muscles was proposed by Deimel and Brock (2016) and the final result for each silicone used can be seen in figure 2. Number 3 is the one made with Dragon Skin FX-Pro®.

Figure 1. Articulated Hand Replica

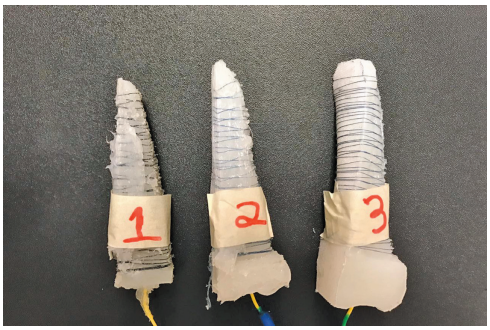

Figure 2. Pneumatic muscles made with different silicones.

The third part was the elaboration of a force sensitive voice control system. A Raspberry PI 3B+ with Snowboy® was used for the control system. Snowboy® is a software with libraries that can be used with Python® and it is designed to allow the use of voice control via the use of Hotwords. For this project the commands that were used were “Ortesis Abre” y “ Ortesis Cierra” (Spanish for “Orthosis, open” and “Orthosis, close” respectively). This commands were used to indicate the controller which function to carry out. Also, to control the force of grasping of the orthosis, the sensors used were Force Sensitive Resistors. This sensors were used to feedback the Raspberry PI with the grasping force values that each finger is making so that it is able to know when the object is being successfully grabbed. Tests with volunteers were done to know the necessary force values for the successful grabbing of different objects.

Results

The result of this project is a soft orthosis that is able to grab objects with different forms and hold them up in the air. Said orthosis was capable of grabbing bottles, cans and rectangular

juice boxes. Also, it was observed that the orthosis inputs strength mainly in the thumb but also in all the other fingers. It was also verified that the model of the hand of the patient can fit in the orthosis. The results can be seen in figure. 3.

Figure 3. Hand Orthosis Grabbing a Bottle

Recommendations

For the next steps of this project it is recommended to optimize the design of the muscles with a silicone that is more resistant and a thicker reinforcement helix. Also, it is recommended to start carrying out the tests of the orthosis with the model of the hand inside it. Another important next step is the implementation of a flexible thumb, this is because the one used right now only has one direction of movement. The implementation of a flexible thumb will be an important step in achieving that the orthosis is able to grab a bigger amount of objects with different forms.

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