A NEW FABRICATION METHOD FOR A COMPUTER CONTROLLED ARTIFICIAL HAND WITH ELECTRIC ACTUATORS

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Abstract: This paper presents a new artificial anthropomorphic hand, focusing on the concepts that allow a modern control strategy having in centre the computer and a modern fabrication method based on a 3D printing process of the mechanical parts that compose the artificial hand. The artificial hand presented in this paper can be used for an amputee as a hand or upper limb prosthetic device or for a robot as a gripping device. Although similarities can be found between prosthetic and robotic hands (mechanical model, actuation, sensors) one can state also the main difference between the two: the method of control which is based mainly on mioelectric signals in the case of prosthetic hands rather than various signals collected from the exteroceptive and proprioceptive sensor system.

Key words: rapid prototyping, computer control, artificial hand.

1. INTRODUCTION

Creating artificial devices similar to those made by nature, in terms of control, fabrication, aesthetics and general performance has always been a human feature. Nowadays we assist at a fervent revolution in robotics, the scientists all around the world presenting artificial intelligence which has features close to those of a human being. This paper treats the basic concepts of creating such artificial device from the fabrication of the parts needed to construct the artificial anthropomorphic hand to the embedded control strategies for the hand. A modern prototyping method for the mechanical model of the hand is described in detail. Also, the automatic control system based on computer written algorithms is another point of interest for this paper.

One major challenge in this field is to get as close as possible to the natural model of the hand in terms of movements, speed, mass, force capabilities, etc. Taking into account these goals a great number of robotic hands have been created in the last years. Some examples are shown further on. The Shadow Hand C5 is an anthropomorphic robotic gripper very similar with the human hand. The actuation system is based on 40 pneumatic actuators (artificial muscles) coupled with cables and routed through fingers pulleys.

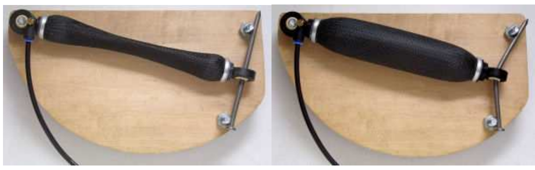

Fig. 1. The Shadow artificial muscles [6]

The pneumatic actuators (8 for each finger) are controlled by a microprocessor which takes into account the information from the various sensors mounted into the hand (Hall Effect for joint rotation, pressure for measuring the pressure in each artificial muscle).

Fig. 2. The Shadow C5 robotic hand [5]

One of the most important accomplishments in this field is the Cyberhand, developed by an international team of researches conducted by the ARTS Lab Scuola Superiore Sant'Anna, Pisa, Italy. The Cyberhand has five fingers, three phalanxes per finger and independent actuation system for each finger. The degree of freedom for the mechanism is M = 16 (the four fingers can perform flexion-extension movements, while the thumb can do, besides flexion-extension, the adduction-abduction movements). Cyberhand is electronically actuated and controlled by a number of six DC motors and a great number of sensors (position, force, pressure, etc.).

Fig. 3. The Cyberhand [2, 3]

The DLR II robotic hand was created by the German Aerospace Center. This robotic hand is equipped with four identical fingers (three fingers and a thumb), each with three D.O.F. (where D.O.F. stands for degree of freedom). An additional D.O.F. is conferred to the wrist. For the actuation system DC motors coupled with cables tendons are employed.

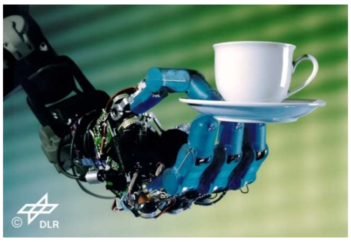

Fig.4.The DLR II robotic hand [1]

The next hand was created to be implemented on the autonomous robot ARMAR. The mechanical model has 11 joints of which 8 are directly actuated. The actuation system is based on fluidic actuators, the pressure being produced by an electronically controlled micropump concealed in the palm.

Fig. 5. The ARMAR end-effector [4]

2. A NEW ARTIFICIAL HAND

After a thorough study of the similar solutions we decided to construct an artificial gripper with three fingers: two identical with three phalanxes and a nonopozable thumb with two phalanxes. The mechanical model allows 8 degrees of freedom. The thumb axis is positioned at 45° from the other fingers axis in relation to the palm.

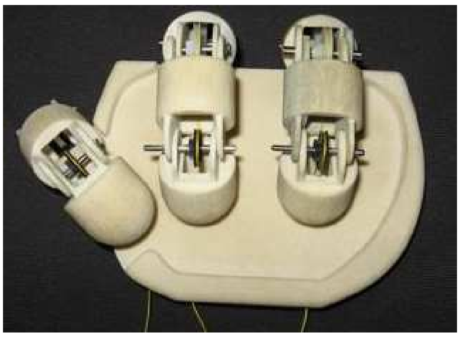

Fig. 6. The new artificial hand

The dimensions of the phalanxes are very close to those of the human hand (see Figure 7).

Fig. 7. A direct comparison of the dimensions of the artificial finger with the human finger

3. FABRICATION OF THE PARTS

For the fabrication of the robotic hands traditional method are used: metal or resin casting, plastic moulding, etc.

In contrast with the traditional methods used for this type of parts we employed a novel approach: the Rapid Prototyping Method.

Rapid Prototyping is a modern metod of obtaining in real time almost any desired prototype. This method combines a 3D printer, CAD development software and, of course, special materials from which the prototype will be created.

Fig. 8. The Zcorp 3D printer used for fabrication

The first step was to create the virtual model of the artificial hand. We used SolidWorks software which allowed us to check the correct closing of the fingers.

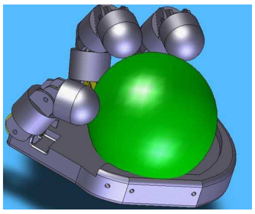

Fig. 9. The virtual model of the hand in solidWorks

The second step was dedicated to the fabrication process. A special powder was the main material for the fabrication process in which the tridimensional model of a part is split in houndreds of slices (the thickness of a slice is measured in microns). For every slice the 3D printer mixes this basic material with another two chemicals resulting an accurate model of the part. After this process, which could take a few minutes or hours, depending on the prototype, the parts are baked for another hour in the machine. After the baking process the surface of the parts hardens, preparing the parts for the next stage in which a mix of two resins in a certain quantity is used for brushing or even submerging the parts. This last process hardens the surface of the parts even more to the point in which, if desired, the parts can be successfully machined afterwards.

4. THE CONTROL SYSTEM

A modern control strategy should benefit from the latest achievements in mechatronics: microprocessors, actuators, sensors, etc. At the Faculty of Mechanics, Craiova we considered all these prerequisites in order to have an intelligent control system for the new artificial hand. The goal was to have a computer based control system which enabled us to obtain either an automatic or a manual control for the hand.

For this task we used a Toshiba Satellite Pro notebook [7], an Arduino Duemilanove acquisition board [8], a breadboard, potentiometers, DC servomotors, etc.

The control system of the artificial hand is composed by two parts: the software and the hardware. The software was used to develop the automatic or manual control algorithms implemented on the Arduino acquisition board having as the interface the Toshiba Satellite Pro notebook software. The communication between computer and the acquisition board was done using a simple USB A-B cable.

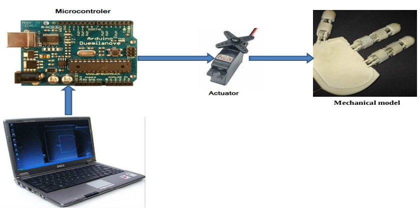

Fig. 10. The components of the control system

The hardware includes: notebook, the acquisition board, the connection cables between them, the breadboard, the potentiometers and the DC servomotors.

A brief description of these components and their role is done next:

- ✓ The Toshiba Satellite Pro notebook ensure the programming interface for the Arduino Duemilanove;
- ✓ The Arduino Duemilanove commands the servomotors for each finger according to the program stored in the internal memory. It is equipped with 19 I/O pins, coaxial power jack for a battery based power supply, USB and it is buid around the Atmel Atmega 328 microcontroller (www.atmel.com);

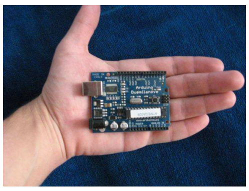

Fig. 11. The Arduino Duemilanove board

- ✓ The breadboard is a device used in electronics for prototype circuits. We used the breadboard to make solderless connections between the Arduino board, servomotors, potentiometers, etc.

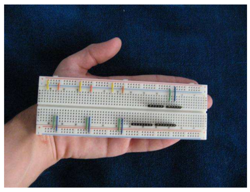

Fig. 12. The breadboard

- ✓ The potentiometers are used for the manual command of the hand. Rotating a knob mounted on the potentiometer shaft anticlockwise will cause the finger to flex, while rotating the knob clockwise will cause the finger extension.
- ✓ The Servomotors are electric actuators which include in the same housing a DC motor, a mechanical transmission and a potentiometer for detecting the position of the output shaft. The servomotors drive the fingers of the artificial hand. We have chosen these actuators over the other actuators (pneumatic, hydraulic, unconventional, etc.) due to the following advantages: high output torque for small dimensions, small mass (starting from 4g per actuator), low energy consumption (the current nedded to drive such an actuator is max 500mA), the movement range of 0-180 ° of the output shaft which is appropriate for this application, compatibility with the other control components (computer, aquisition board), accurate positioning of the output shaft with increments of 1°, cost, etc. Few technical specifications of the Tower Pro SG-5010 DC servomotors: dimensions 40x20x38 mm, mass 41 g, torque 65 Ncm (at 6V), speed 0, 16 s/60°.

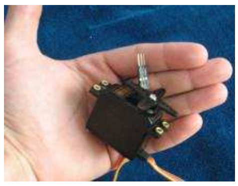

Fig. 13. The DC servomotors [9]

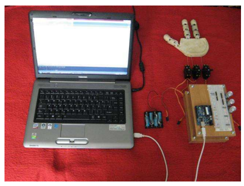

Fig. 14. A picture with all the components of the control system before making the assembly

The servomotors are commanded using Pulse Width Modulation method by the Arduino board which has 8 channels for PWM.

The programmes for the automatic or manual control mode are written in a C based language. The programmes allow controlling the speed, amplitude and timing of the fingers movement just by changing a few simple parameters. After a program has been uploaded to the Arduino Duemilanove acquisition board, the program is stored and computer becomes redundant. Therefore, an important application of the artificial hand presented in this paper is the medical prosthetic field. A patient with amputated hand or upper limb could use this artificial hand for day by day grasping tasks. In the future we intend to implement a proximity ultrasonic sensor mounted in the palm and force resitive sensors on the phalanxes. Intelligent control algorithms will be created in relation to the signals from the sensors. For example, using the ultrasonic sensor we could create a program which will order the hand to grasp an object if the distance between palm and object is 2 cm. In a similar manner we could create a force control algorithm which will have as a variable the force between the phalanxes and the grasped object. We intend using these sensors in order to augment the exteroceptive capabilities of the artificial hand for prosthetic applications. Of course, the ultimate goal is to have myoelectric based control system in order to consider this artificial hand a modern prosthetic device.

5. EXPERIMENTAL TESTS

In order to illustrate the potential of this new developed artificial hand and the correct approach described in this paper we present a few pictures in which various objects are being grasped by the artificial hand. In Figure 15 we used an adhesive tape, in Figure 16 a scissor, in Figure 17 a small box, while in Figure 18 a coffee plastic recipient.

Fig. 15. Grasping an adhesive tape

Fig. 16. Grasping a scissor

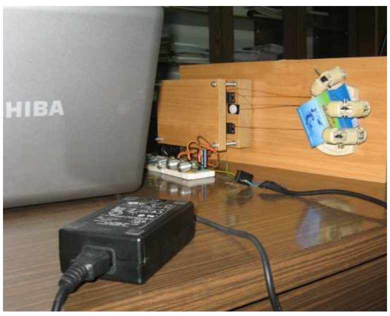

Fig. 17. Grasping a small cardboard box

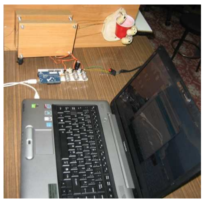

Fig. 18. Grasping a plastic coffee recipient

6. CONCLUSIONS

Rapid Prototyping is a modern, fast, accurate manufacturing method for almost any prototype;
Artificial hands strive to achieve the capabilities of the human hand in terms of general performance;
The artificial hand discussed in this paper has applications either in medicine (as prosthetic device for human hand or upper limb) or in robotics (as a robotic end-effector);
The control system of the artificial hands is based on the latest generation of mechatronic components;
Using the DC servomotors as actuators we obtained a precise positioning for the fingers, good force capabilities and low cost solutions.

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