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ON THE DEVELOPMENT OF A ARTIFICIAL HAND WITH PROSTHETIC OR ROBOTIC APPLICATIONS

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ABSTRACT:
In this paper we present a new developed artificial gripping device which can be used in robotics as a robot end-effector or as prosthetic device for patients with amputated hands. The main topics of this research are the novel fabrication method of the mechanical parts that compose the hand, the actuation system, the computer based control system and the experimental tests carried with this artificial hand device.
KEYWORDS:
artificial hand, computer control, robotic, prosthetic

1. INTRODUCTION

In the past 20 years a great number of artificial grippers have been developed for industrial applications or as laboratory research products [3, 8, and 9]. In the industrial environment we find a vast array of non anthropomorphic mechanical grippers used from the food processing industry to the automotive industry. The mechanical model of these grippers is often characterized by a small number of D.O.F.s which leads to a reduced gripping potential and poor performance [14]. For the industry their capabilities are satisfactory, but in applications where the array movement of the mechanical parts is complex the industrial grippers are not the solution.

For example, in the robotic or medical prosthetic field the prerequisites for such products are: force capabilities close to those developed by human hand, modern sensing devices, aesthetics, mass, friendly control interface and exact movement replication as the human hand. The last condition can be solved only by designing a mechanical model with enough degrees of freedom. Therefore, the mechanical model for such a device should be developed by comparison with the human hand which possesses only at the phalanxes level 19 DOF [13].

The human hand is made of palm and five fingers: a thumb which has 3 DOF and four fingers with 4 DOF each. A finger consists of metacarpal bones (MP), proximal interphalanx (PIP), medial interphalanx (MIP) and distal interphalanx (DIP). The typical movements of the human hand fingers are: flexion-extension and adduction-abduction for the MP- PIP joint and flexion-extension for PIP-MIP and MIP-DIP joints.

Many researchers have constructed various artificial anthropomorphic hands by similarity with the human hand. A few artificial hands constructed in recent years reach performances close to those of the human hand in terms of aesthetics, force capabilities, degrees of freedom, mass, sensorial system, etc.

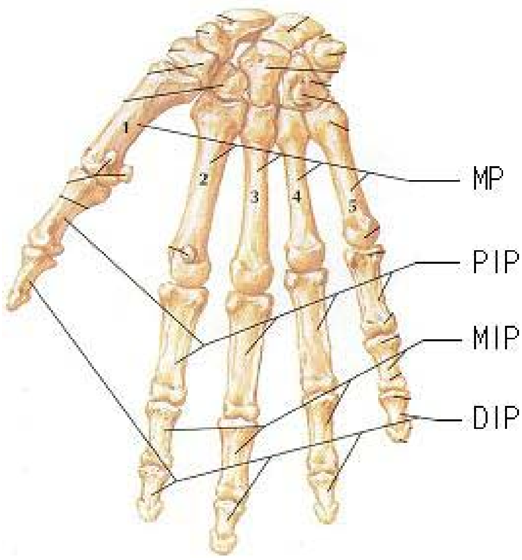

Figure 1- The mechanical model of the human hand [11]

One of these artificial hands is Shadow Hand C5 [15]. The actuation system is based on 40 pneumatic actuators (artificial muscles) coupled with cables and routed through fingers pulleys. The pneumatic actuators (8 for each finger) are controlled by a microprocessor which takes into account the information from the various sensors (Hall Effect for joint rotation, pressure for measuring the pressure in each artificial muscle). The thumb has 5 degrees of freedom and 5 joints, while the other fingers have 3 degrees of freedom and 4 joints. All joints except the finger distal joints are controllable to +/- 1° across the full range of movement.

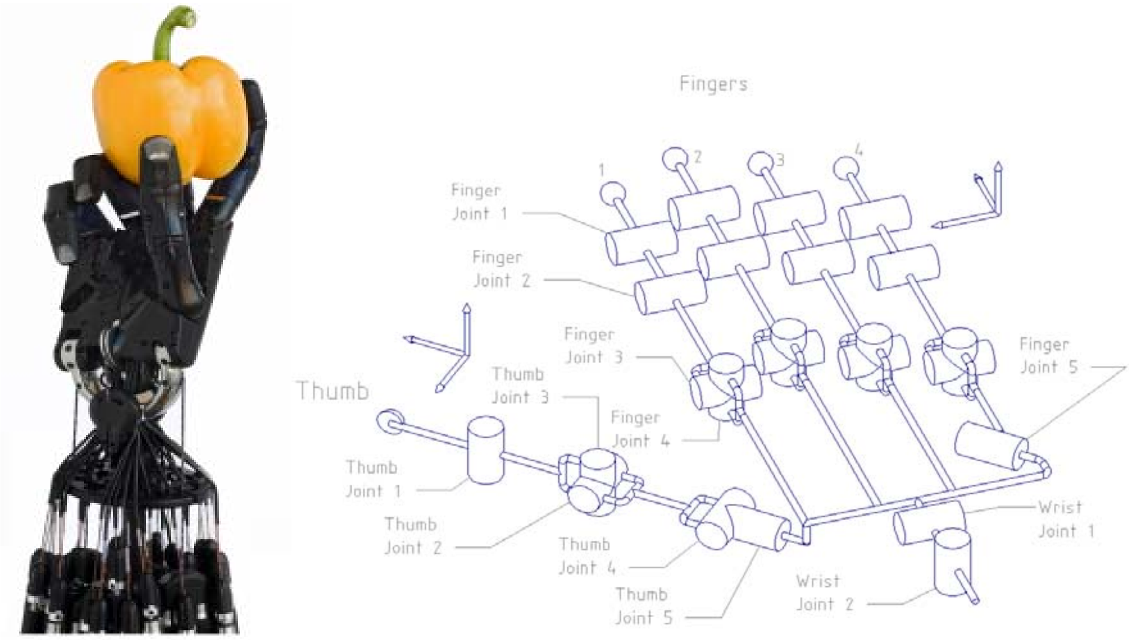

Figure 2 – Shadow Hand C5 (a picture of the hand and kinematical scheme)

Another example of modern artificial hand is the ICU hand [5]. Developed by a team of researchers at the University of Seoul, the ICU hand consists of five fingers (four identical fingers and a thumb). The hand has 14 mechanical joints and 10 D.O.F.s (one D.O.F. is eliminated by coupling the medial and distal phalanxes through a four bar link mechanism). Interesting about this robotic hand is the fact that it can produce human like features such as: palm temperature variation, sweating, trembling, grasping force variation according to the external object.

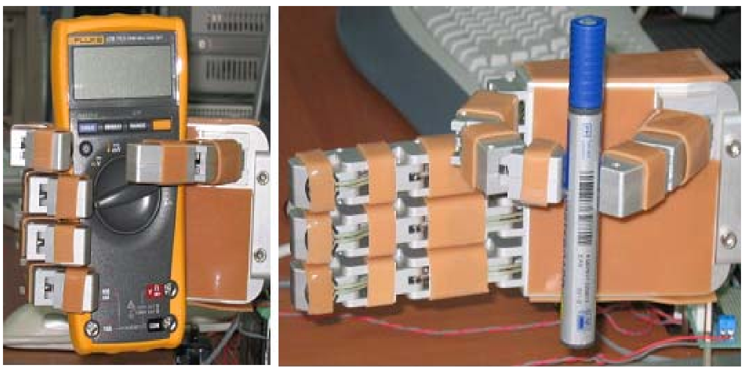

Figure 3 – The ICU hand

One of the most important accomplishments in this field is the Cyberhand [1, 2], developed by an international team of researchers 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 by a number of six DC motors and controlled with a great number of sensors (position, force, pressure, etc.).

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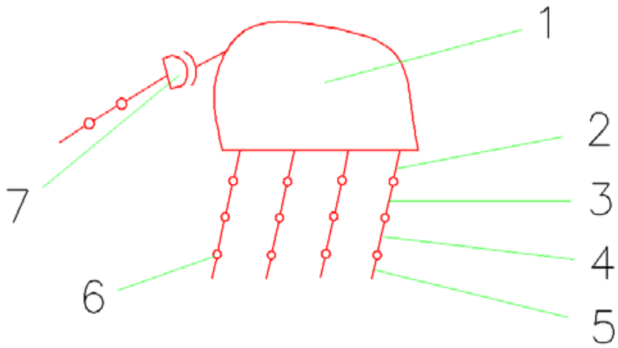

Figure 4 – The Cyberhand (a picture of the hand assembly and kinematical structure), where: 1- palm, 2 – MP, 3 – PIP, 4 – MIP, 5 - DIP, 6 – one degree of freedom joint, 7 – two degrees of freedom joint of the thumb

2. THE NEW ARTIFICIAL HAND

After a thorough analyze of the existent artificial hands we decided to construct a three fingered hand which will be controlled by computer. Next, we will explain the basic steps in the development of this artificial hand device. First, we adopted the kinematical structure of the hand.

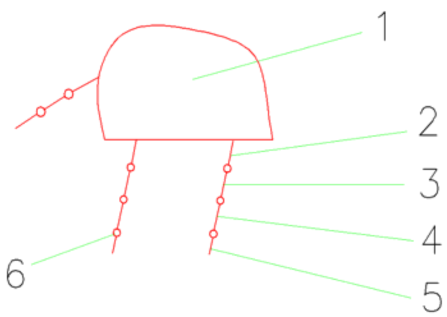

Figure 5 - The kinematical structure of the hand, where: 1- palm, 2 – MP, 3 – PIP, 4 – MIP, 5- DIP, 6 – one degree of freedom joint

Based on the kinematical scheme, we began constructing a tridimensional model of the hand using SolidWorks CAD software.The parts needed to construct the hand assembly have been fabricated using rapid prototyping method at the Faculty of Mechanics, Craiova. This method had enabled us to create a desired part directly from the CAD model. The anthropomorphic hand from this paper possesses a palm and three fingers (two identical fingers and a thumb). The thumb is made from two phalanges (distal and proximal), while the other fingers have three phalanges (distal, medial and proximal). The angle between thumb axis and the other fingers axis is 45°. The degree of freedom for the mechanism of the hand is M = 8.

Figure 6 – The 3D model developed in SolidWorks, the resulted artificial hand and the 3D Zcorp printer used for parts fabrication

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3. ACTUATION SYSTEM

The actuation system of the artificial hands can include electric [7], pneumatic [12], hydraulic [4] or unconventional actuators [10]. In some embodiments, a combination of cited actuator categories is used [6]. Each category of actuators presents advantages or disadvantages.

For example, electric actuators (DC/AC motors, DC servomotors) can be implemented because they have small dimensions, are lightweight, the energy consumption is low, can be easily controlled electronically, etc. Some of their shortcomings are: the noise, the necessity of using transmissions to amplify the moment and reduce speed, etc.

The pneumatic actuators provide good force capabilities, have reduced mass and gauge, flexibility, insignificant wear, can be easily replaced, can work in harsh environments (under water, sand, corrosive agents, etc.) and have no need for additional transmissions.

The hydraulic actuators ensure good force characteristics, but they require additional components like tanks, valves, pipes, etc. which, very often, lead to an unsatisfactory gauge.

The unconventional actuators used for the artificial hands are the memory shape elements. These actuators convert electrical energy (heat) in mechanical work. They are lightweight, noiseless, can deliver a huge amount of force per wire cross-section (which can exceed 200 MN/sqm), but they have a poor mechanical efficiency, which lies somewhere around 3% with full recovery of the heat associated with the thermal consumption. A good compromise can be obtained by using a hybrid actuation [6].

Based on these considerations, for this project we have chosen electric actuators (DC servomotors) for the following advantages:

- high output torque for small dimensions;
- small mass (starting from 4g per actuator);
- low energy consumption (the current needed 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, acquisition board);
- accurate positioning of the output shaft with increments of 1°;
- cost.

In our design a DC servomotor coupled with cable transmissions drives a finger of artificial hand. Therefore, we can asses that the hand has an independent actuation system for each finger. Few technical specifications of the Tower Pro DC servomotors: dimensions 40x20x38 mm, mass 41 g, torque 65 Ncm (at 6V), speed 0, 16 s/60°.

4. COMPUTER BASED CONTROL SYSTEM

In our vision a modern artificial hand should contain the latest achievements in mechatronics: actuators, sensors, microcontrollers and to have a computer based control system. Our goal was to find the scientific approach which could lead to modern control strategy for the artificial hand. For this task we combined a computer (Toshiba Satellite Pro notebook), an acquisition board (Arduino Duemilanove) equipped with a microcontroller (Atmel Atmega 328) and the DC servomotors. The DC servomotors are commanded by the acquisition board using Pulse Modulation Method. The acquisition board is programmed in a C based programming 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.

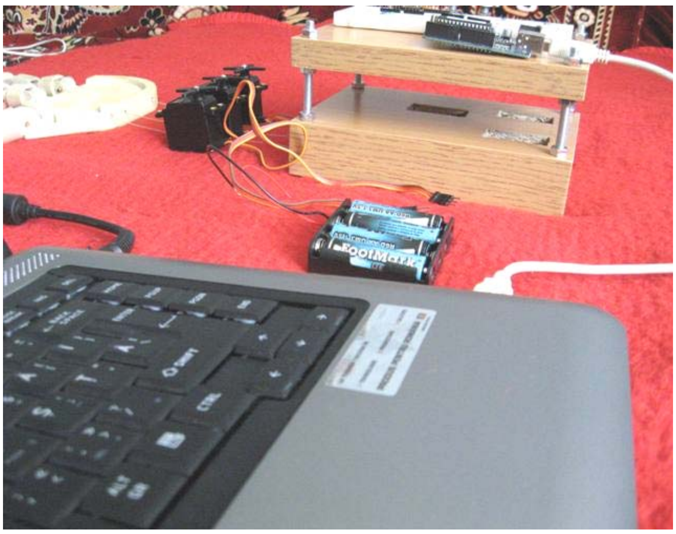

Figure 7 – The components of the computer based control system

5. EXPERIMENTAL TESTS

After all the components of the control system have been assembled we carried out a few grasping tests with diverse objects. Among those object we can record: an apple, a small cardboard box, plastic recipients, a scissor, etc. The artificial hand exhibits good force characteristics, soft objects being firmly gripped. For not damaging extrasoft objects (for example eggs) force sensor control algorithms are mandatory. The closing speed and timing of the fingers are very similar to those of a human hand.

Figure 8 – Grasping a scissor

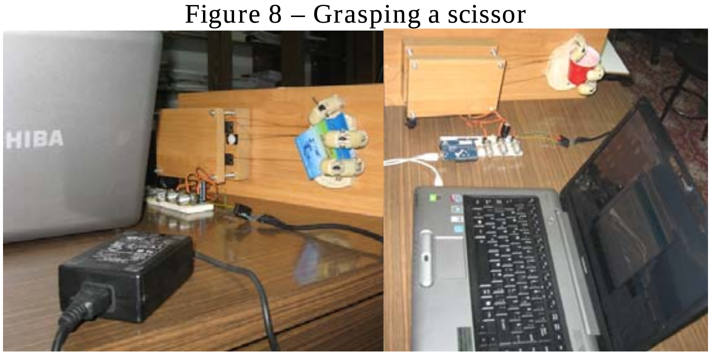

Figure 10 – Grasping a small cardboard box (left) and a plastic recipient (right)

6. CONCLUSIONS

Based on this research one can conclude that:

- Anthropomorphic grippers are constructed by similarity with the human hand;
- The artificial hand treated in this paper can be used in robotics or medical field;
- Rapid Prototyping Method is a state-of-the-art, fast, accurate method for real time prototyping;
- Embedded control is a modern control strategy for the new generations of robotic hands;
- Electric actuators (DC servomotors) in conjunction with specific hardware and software allow precise control and cost effective solutions;

REFERENCES

[1.] Carrozza, M.C., Dario, P., Vecchi, F., Rocella, S., Zecca, M., Sebastiani, F., The Cyberhand: on the design of a cybernetic prosthetic hand intended to be interfaced to the peripheral nervous system;

[2.] Dario, P., Miccera, S. Menciassi, A., Cyberhand – A consortium project for enhanced control of powered artificial hand based on direct neural interfaces, 33rd Neural Prosthesis Workshop, Bethesda, MD, USA, Oct. 16-18, 2002;

[3.] Jacobsen, S. C., Iversen, E. K., Knutti, D.F., Johnson, R.T., Biggers, K.B. – "Design of the Utah-MIT Dexterous Hand", Proc. IEEE International Conference on Robotics and Automation, April 7-10, 1986;

[4.] Kargov, A., Asfour, T., Pylatiuk, C., Oberle, R., Klosek, H., Schulz, S., Regenstein, K., Bretthauer, G., Development of an Anthropomorphic Hand for a Mobile Assistive Robot, IEEE 9th International Conference on Rehabilitation Robotics: Frontiers of the Human-Machine Interface, Chicago, Illinois, USA, June 28-July 1, 2005;

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[5.] *Kim, K., Hwang, Y., Song, W., Lee, M. – Robotic Hand with Object-Manipulation and Emotion Expression Capabilities, Digital Media Laboratory, Information and Communications University, Seoul, Korea;*

[6.] *Mândru, D., Cosma, A., Lungu, I. – Anthropomorphic artificial hand with hybrid actuation, Proceedings of the International Conference Robotics'08, Braşov, Romania, Nov 13-14, 2008;*

[7.] *Matsuda, H. et. al. – Multifingered Hand Device , US Patent no. 6517132 B2, Feb. 11, 2003;*

[8.] *Mouri, T., Kawasaki, H., Yoshikawa, K., Takai, J., Satoshi, I. – Anthropomorphic Robot Hand: Gifu Hand III;*

[9.] *Ruoff, C. et. al. – Multi-Fingered Robotic Hand, US Patent no. 4921293, May 1, 1990;*

[10.] *Rush, J. – Memory Wire Robotic Hand, US Patent no. 5647723, Jouly 15, 1997;*

[11.] *Sinelnikov, R.D. - Atlas de Anatomia Humana, Editura MIR, Moscova, 1975;*

[12.] *Shadow Robot Company, Design of a Dextrous Hand for Advanced CLAWAR Applications. Available from: http://www.shadowrobot.com/downloads/dextrous_hand_final.pdf;*

[13.] *Stareţu, I. – Sisteme de prehensiune, Editura Lux Libris, Braşov, 1996;*

[14.] *Sundar, N. – Dexterous Robotic Hands: Kinematics and Control, MIT Artificial Intelligence Laboratory;*

[15.] *www.shadowrobot.com/downloads/shadow_dextrous_hand_technical_specification_C5.pdf;*

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