RAPID PROTOTYPING AND EMBEDDED CONTROL FOR AN ANTHROPOMORPHIC ROBOTIC HAND

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*Abstract: This paper presents the basic steps in the development of an anthropomorphic robotic hand. A rapid prototyping method for parts fabrication and embedded control method of the robotic hand are the main topics of this paper.
Keywords: robotic hand, embedded control, rapid prototyping.*

1. INTRODUCTION

The pursuit of creating artificial intelligence that could compete with the models created by nature has always been a challenge for researches all around the world. In the robotic area progresses have been recorded through intensive research in the last two decades. Alongside with the new generation of robots, the prerequisites for robotic end-effectors have changed in terms of control, fabrication, aesthetics and general performance. 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. A few examples are shown next.

The Shadow C5 robotic hand [1, 2] is very similar to the human hand. This hand possesses 24 degrees of freedom; actuation is based on 40 artificial muscles coupled with cables and routed through fingers pulleys.

Figure 1- The Shadow Robotic hand

The i-Limb Hand [3] is considered one of the most capable prosthesis for the hand or upper limb. This anthropomorphic hand possesses five fingers, each with two phalanxes (the degree of freedom for the mechanism of the hand is M = 11). Te actuation is made by five DC motors placed in the palm. Working as prosthetic device is enabled by two electrodes bonded to the patient skin which collect the myoelectric signals from the muscles and transmit these signals, together with the information from the sensors, to a microprocessor.

The DLR II robotic hand [4, 5] has four identical fingers (three finger and a thumb), each with three D.O.F.s. An additional D.O.F. is conferred to the wrist. For the actuation system DC motors coupled with cables tendons are employed.
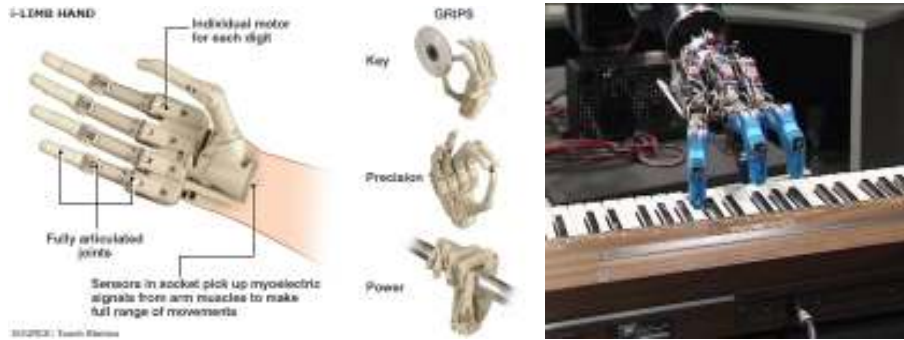
Figure 2 – The i-Limb hand and DLR II Robotic hand

The next robotic hand [6] 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 produces by an electronically controlled micropump concealed in the palm.

Figure 4 – The end-effector created for robot ARMAR

The ICU robotic hand [7] comprises 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.
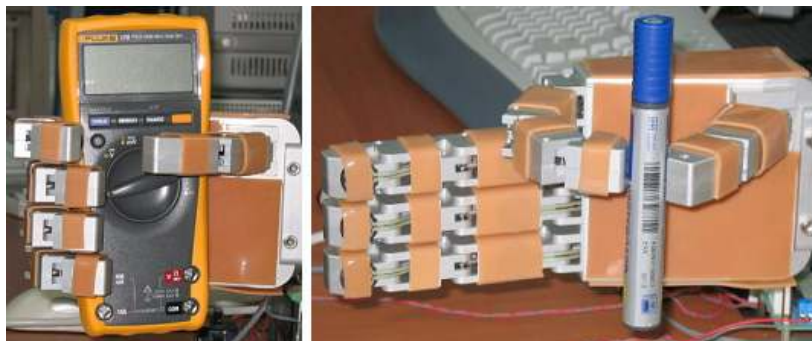

Figure 5 – The ICU robotic hand

The control system of the robotic hands presented above is based on last generation mechatronic devices such as: microprocessors, sensors and actuators. For the fabrication of the mechanical parts traditional methods are employed: metal casting, plastic moulding, etc. Even some of the actuators used are custom developed for that particular application.

2. RAPID PROTOTYPING

Rapid Prototyping is a method of obtaining in real time almost any desired prototype. This method employs a 3D printer, CAD development software and, of course, special materials from which the prototype will be created. In contrast with the traditional methods, Rapid Prototyping method allows the user to create precise (the accuracy of the model goes down to the microns level), robust prototype in a few minutes or hours (depending of the model).

At the Faculty of Mechanics, Craiova, we used all this features in order to fabricate the parts needed for the construction of the robotic hand. First of all, a 3D Zcorp printer connected to a PC was used.

Figure 6 – The 3D Zcorp printer used for fabricating the parts

The software that enabled us to create the virtual model of the parts was SolidWorks. With this software we could see the correct closing of the fingers, with or without object grasping.

Figure 6 – The palm (left) and finger construction (right)

Figure 7 – Simulations with the virtual model of the hand

3. THE ANTHROPOMORPHIC ROBOTIC HAND

Following the parts fabrication process was assembling process to create an anthropomorphic hand. The resulted robotic hand has three fingers (two identical with three phalanxes and a thumb with two phalanxes). The angle between thumb and finger axes is 45°. The mechanical design allows 8 D.O.F.s for the entire hand.

Figure 5 – Some pictures with the fabricated parts and the assembled model

4. ACTUATION SYSTEM

The actuation system of the robotic hands is based on the following categories of actuators: electric, pneumatic, hydraulic, hybrid or unconventional actuators. Each category has its own advantages and disadvantages.

For example, electric actuators [8] (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 [8] 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 [9] 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 robotic 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 [10]. A good compromise can be obtained by using a hybrid actuation.

For the anthropomorphic robotic hand treated in this paper we have chosen an electric actuator based system. Each finger is driven by a DC servomotor coupled with cables routed through finger pulleys. Few technical specifications of the servomotors: dimensions 40x20x38 mm, mass 41 g, torque 65 Ncm (at 6V), speed 0, 16 s/60°.

Figure 6 – The Tower Pro SG-5010 DC servomotors [11]

5. EMBEDDED CONTROL

In order to have an automated control system for the robotic hand we employed a microcontroller which establishes the position of the servos axe according to a memorized programme written in C language.

The embedded control can be split in two parts: the hardware and the software. In the first one we can include: the PC (or notebook), the acquisition board, the connection cables between them, the storage devices, etc. The software in based on the microcontroller running programme and the PC (notebook) software.
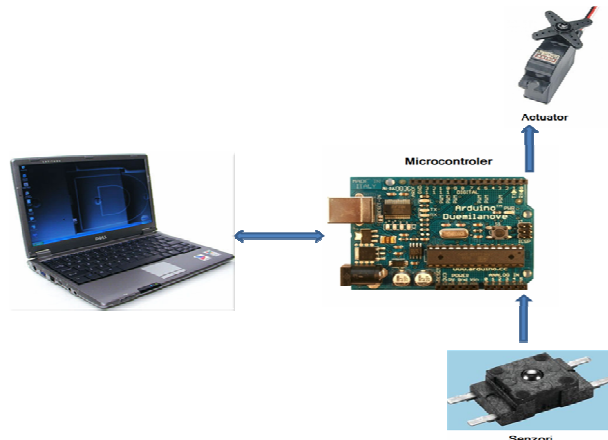

Figure – The hardware used to control the robotic hand

We have chosen the Arduino Duemilanove acquisition board for this project. Based on an ATmega 328 microprocessor (www.atmel.com), this board is equipped with 19 assignable I/O (13 digital and 6 analogue), a USB input to communicate with a PC, a power jack for an external power supply based on batteries, etc.

Figure 9 – The Arduino Duemilanove board [12]

The goal was to control the fingers movement by means of potentiometers connected to the Arduino board.

Turning a knob mounted on top of the potentiometer in one sense will cause the lever mounted on the servomotor output shaft to rotate thus flexing the finger, while turning in the other sense will cause the finger extension.

To ensure a solder less connection of the servomotors and potentiometers to the Arduino Duemilanove we used a breadboard. A breadboard is a device used in electronics for prototype circuits, facilitating the connection of various electric components (be it integrated circuits, diodes, transistors, capacitors, resistors, etc.) without being constrained to make soldered connections.

The control system allows the user to control the robotic hand either manually (rotating the potentiometer knobs) or automatically by loading a new program in the Arduino Duemilanove board.

The manual control program and the automatic control program that enables the Arduino board to command the servomotors are shown in Figure 11.

Figure 10 – A picture with the control system components

Figure 11 – The programmes written for the Arduino Duemilanove board

6. EXPERIMENTAL TESTS AND CONCLUSIONS

Several grasping tests have been performed in order to certify the correct approach presented in this paper. The use of servomotors (which can be controlled to rotate down to increments of one degree) allows precise positioning of the fingers. Moreover, the use of potentiometers in the manual control mode enables the user to select the desired closing/opening speed of the fingers.

In the following pictures we present some object grasping examples:

Figure 12 – A few pictures with grasped objects

Based on this research one can conclude:
  i.   Rapid Prototyping Method is a state-of-the-art, fast, accurate method for real time prototyping;
  ii.   By combining Rapid Prototyping Method and any CAD software almost any prototype is obtainable;
  iii.   Embedded control is a modern control strategy for the new generations of robotic hands;
  iv.   Electric actuators (Dc servomotors) in conjunction with specific hardware and software allow precise control and cost effective solutions.

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