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Fuzzy Control for Cylindrical Grasp in Anthropomorphic Hand

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Abstract

This paper shows the control of a robotic anthropomorphic hand. The prototype is a modification of a design previously made by the ARMOS research group. This hand has as objective to perform a cylindrical grasp in a way that is trustworthy for a plastic bottle, using an arrangement of RFS sensors (Resistive Force Sensors) placed in the tips of the fingers, and servomotors that will perform the closing movement. The control scheme uses fuzzy logic as the smart decision strategy. The results on the prototype demonstrate the high performance of both the robot and its control scheme.

Keywords: anthropomorphic, control, fuzzy, grasp, robot

1 Introduction

The design and development of control schemes for anthropomorphic hands must take into account key elements such as: sensors, actuators, degrees of freedom, construction materials, grip reliability and the robot desired purpose.

There is a lot of research in this field. For example, in [5] there is a hand composed of five fingers, with a total of 19 degrees of freedom. The thumb proposed has a special design that improves its application, and whose structure has inspired our design. The fingertip joint of all fingers (except the thumb) is attached to the joint by a linking mechanism, the palm has a unique design in order to improve grip in terms of firmness and accuracy. The size of the hand is close to that of a human hand. For maintenance, the fingers from the bud to the base of the palm are uncoupled, i.e. each finger can be individually modified if necessary. All actuators, mechanical parts, and sensors are located in the hand. The general design scheme has been adopted in our prototype.

In the [7] prototype, the mechanism is designed to be the grasp part of the prosthesis. The main peculiarity of the device is essentially that it is based on an adaptive scheme, and in this way the system is able to make the three phalanges of each finger adapt to the shape of the gripped object. This is achieved by means of non-extensible tendons, which allow the object to be grasped independently of the configuration of the finger itself and the other fingers. Pulleys are used to simulate the force required by the hand to grasp the object regardless of its shape.

As for motion transmission, there are proposals such as [9], where a transmission system with motors in the joints (DLR hand) is implemented. With this system there is independence in the joints, and more complex finger movements can be achieved. Position and force sensors have also been fitted to the hand. The prototype has a hardware/software interface that allows sensory feedback, and actuation to perform grasping postures. A similar idea is developed in [3].

Other proposals also show improvements in actuators. This is the case of [1], in this research there is a methodology based on states. The control system uses blocks of instructions that are put into operation according to the sensed state. Also interesting is the design strategy used in [10], which uses computed tomography to design and model the hand, recreating its internal and external image. This design shows the minimum and maximum degree of extension, the thumb opposition movement that develops without any problem and the classification of grip types according to the position of the hand towards the object hitch.

In [8], the study of the grasp is carried out according to the points of pressure and force applied when the grip is made. The study is performed for cylindrical grip, which is generally considered to be the most important. It also looks at how ergonomic it should be for easy adaptation. Two measuring systems are used for this purpose: the first is the grip system (tekscan inc.) and the finger TPS (pressure profile systems). The grip system is based on the use of the 4256E sensor, which attaches to a glove forming 18 sensitive zones with a total of 349 sensors. The finger TPS system consists of eight sensitive areas mounted on fabric supports, five of these areas measure the contact strength of the distal phalanges, two in the proximal phalanges of the index and middle fingers, and finally one located in the palm. Each zone has a unique elliptical sensor. Precise values such as the response frequency and pressure supported by each sensor are given in each of the methods.

Some others, such as [11] and [6] show studies from each element of the hand (fingers), getting each finger to be self-adapted to the object it is intended to grip. Each finger has three DOFs in parameters that affect the turning angle and grip force. The grip type is optimized by performing force diagram calculations. In the same way, in [13] and [12] the control of each finger is taken individually, adding more degrees of freedom to the thumb to make the movement towards the palm of the hand.

Finally, an interesting idea of design, also considered in this research, is to implement the bidirectional movement of the fingers, giving to the hand the ability to perform tasks such as unscrewing the cap of a bottle [3].

The paper is organized as follows. In Section 2 we present some preliminary concepts, the functional profile of the prototype and detail the design of the anthropomorphic hand structure, including the selection criteria and final specifications adopted. In Section 3 we present the evaluation of the performance of the prototype. Finally, the Section 4 concludes the paper.

2 Materials and Methods

The control problem to be solved is focused on making a safe grasp of a plastic bottle. The hand has pressure sensors on each finger for individual feedback. The actuators are servomotors, one for each finger, which will force a nylon ligament in response to the behavior of the bottle in the hand [4].

The servos used are TowerPRO SG-5010 with 3 kilograms of force. these servomotors were modified to facilitate connection. The forearm was secured with screws and fastened to the palm with a screw and silicone to ensure that the palm does not move abruptly relative to the forearm. FSR sensors (10 kg resistive force sensors) were used as sensors, which are read with an adjustable voltage tracker.

2.1 Control schema

The fuzzy control design was developed considering the performance of piezoresistive sensors. These sensors provide approximate information (considering the different possibilities of actual grip) as discrete data in the range between 0 and 1023. Servo motors used as actuators have a position range between 0 and 180 degrees. These parameters were used for the definition of fuzzy variables, universes, and membership functions.

In order to achieve control over the grip of the anthropomorphic hand we opted to choose the error of the sensors with respect to the last reading as inputs of the fuzzy control. Therefore, we get five different inputs, each corresponding to each finger. For the output we use the angular position of the servomotors. We use MATLAB for the design and adjustment of the

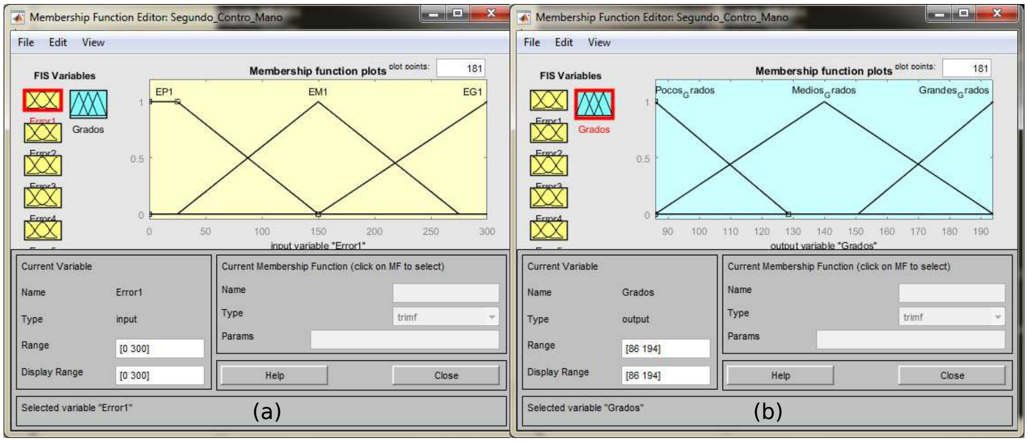


Figure 1: (a) Fuzzy sets of input variables, (b) Fuzzy sets of output variables.

fuzzy control. As interface hardware with sensors and actuators we use a communication card based on the Atmel ATmega328P microcontroller (20 MIPS, on-chip 2-cycle multiplier, six PWM channels, 6-channel 10-bit ADC and 28 programmable I/O lines).

The fuzzy control system runs in real time on the microcontroller. For this purpose, the sensed signals are discretized at 10 bits, and the operations are carried out inside the microcontroller in fixed point [2]. The output to actuators is filtered to an analog value by PWM. We use the same universe for the five inputs selected according to the full scale reading of the sensor (when the bottle is slipping into the closed hand). The membership functions are also the same for each input. We use two triangular membership functions for medium and high error values, and for low values we use a trapezoidal one (Fig. 1(a)). For the output we also use three fuzzy sets (Fig. 1(b)).

The rule base considered the sliding of the bottle, as well as the need for a secure grip but without deforming the object. These rules are summarized in Table 1. For inference we use Mandani, and center of gravity. The control curve of each sensor is shown in Fig. 2(a), and the control surface for two sensors and the output is shown in Fig. 2(b).

3 Results and Discussion

The performance of the control scheme was evaluated during several operation tests with various cylindrical objects, most of them with plastic bottles with different liquid levels. During the tests we verify the grip of the object and the response to slippage by trying to remove the object from the robotic hand. The sensor on each finger detects the presence or absence of the object according

Table 1: Basis of fuzzy rules

Rule base																						
Sensor 1			Condition	Sensor 2			Condition	Sensor 3			Condition	Sensor 4			Condition	Sensor 5			Implication	Output (Deg)		
EP1	EM1	EG1		EP2	EM2	EG2		EP3	EM3	EG3		EP4	EM4	EG4		EP5	EM5	EG5		PG	MG	GG
x			AND	x			AND	x			AND	x			AND	x			Then	x		
	x		OR		x		OR		x		OR		x		OR		x		Then		x	
		x	OR			x	OR			x	OR			x	OR			x	Then			x

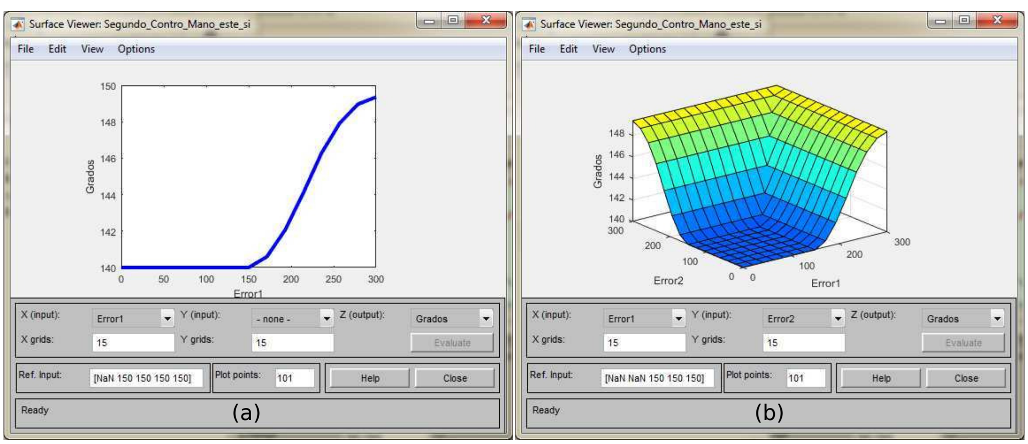


Figure 2: (a) Control curve of each sensor, (b) Control surface.

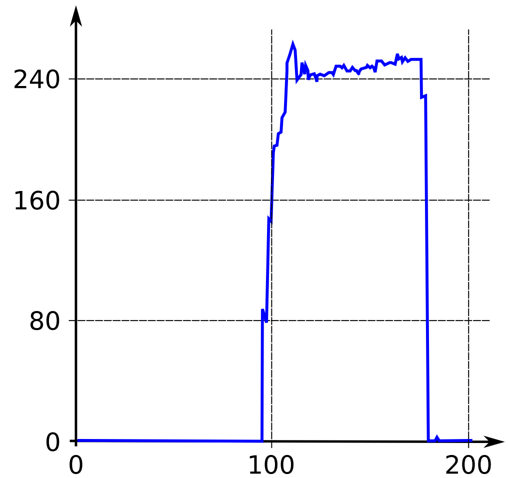


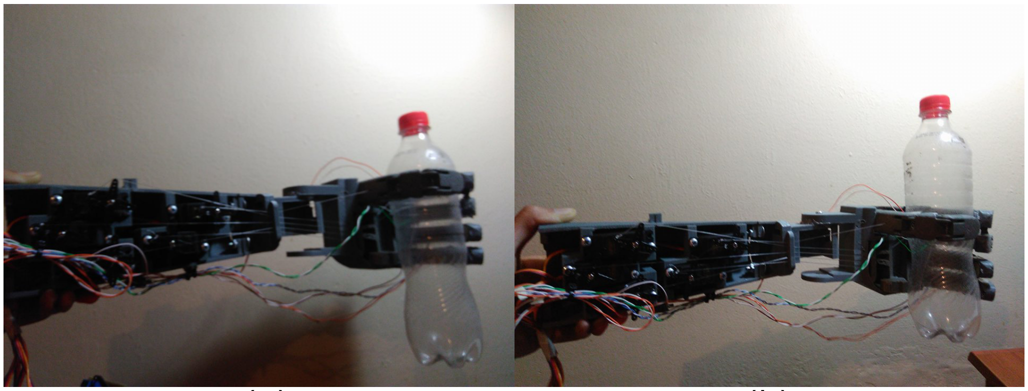
Figure 3: Sensor data on the little finger when detecting the object and pressing on it.

to the pressure level on the sensor (Fig. 3). Safe grip tests were performed with different strategies to remove the bottle from the hand. Some tests were carried out at low speed, others at medium speed and others at very high speed. In all cases the control reacts correctly, trying to avoid the loss of the object (Fig. 4). The object is only removed from the hand under extreme external force.

The control scheme design was conceived for cylindrical objects, in particular bottles and equivalents. However, as part of the performance tests, the prototype was evaluated with other objects, in particular smartphones, glasses and glass cups. In all cases, the hand was able to securely grasp the object. However, in the case of the cup, one of the tests ended with the breakage of the object. This test highlights the need for improved control to ensure user safety, for example in the case of a human handshake.

4 Conclusions

We use the ARMOS research group's anthropomorphic hand prototype to evaluate the performance of a fuzzy control scheme in cylindrical grasp applications. The robot was equipped with resistive pressure sensors on each of its fingers. The sensor signals fed a position control designed from fuzzy rules, with Mandani inference. The control outputs directly activate a servomotor and a sub-actuated mechanism installed on each finger. The control operates on-line and directly on hand, simplifying the code to operate in an 8-bit microcontroller. The performance of the control and hand surpasses expectations,



(a) (b)

Figure 4: (a) Top bottle grip, (b) Bottle bottom grip.

achieving real-time operation, and with a very high degree of robustness. Future enhancements include the addition of control rules for human operator safety.

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