



Fuzzy Control of the Robotic Hands Catching Force Using Muscle Wires Actuator

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Abstract

The aim of this research is controlling the amount of the robotic hand catching force using the artificial muscle wire as an actuator to achieve the desired response of the robotic hand in order to catch different things without destroying or dropping them; where the process is to be similar to that of human hand catching way. The proper selection of the amount of the catching force is achieved through out simulation using the fuzzy control technique. The mechanism of the arrangement of the muscle wires is proposed to achieve good force selections. The results indicate the feasibility of using this proposed technique which mimics human reasoning where as the weight of the caught piece increases, the force increases also with approximately the same amount of increment.

Keywords: *Muscle wires, shape memory alloy, robotics hands.*

1. Introduction

It is still hardly desired to control the motion and catching force of the robotic hand to make an excellent response to catch different things without destroying them or slipping them down.

Pedram Afshar and Yoky Matsuoka [1] indicate that the neural-based control of a robotic hand has many clinical and engineering applications. Current approaches to this problem have been limited due to a lack of understanding of the relationship between neural signals and dynamic finger movements. Here, a technique is presented to predict index finger joint angles from neural signals recorded from the associated muscles. The neural signals were converted to a torque estimate (EBTE) and then input to artificial neural networks. The networks predict the finger position more closely when the input to the networks is torque estimates rather than neural signals.

Vishalini Bundhoo and Edward J. Park [2] focus on the design and modeling of a prosthetic finger for children. Conventional prosthetic hands are simple grippers that only restore the very basic grasping capabilities of the human hand. Novel design methodologies were required in order to

address the issue of low functionality of prosthetic hands while still meeting their mass and size requirements. A biomimetic approach to prosthetic hand design proposed. The musculoskeletal characteristics of the human hand are studied in order to extract elements that are essential in the design of a biomechanically accurate hand. A 4 DOF finger design that closely mimics the size and kinematics of the human finger is presented. The design proposes to use SMA-driven tendon wires that are directly attached to the finger structure, in a manner similar to the natural tendons and muscles. A kinematic analysis of the proposed finger, which defines the relationship between the motion of its joints and the corresponding SMA artificial muscle contraction ranges, was presented. The results of a torque analysis carried out to evaluate SMA wire diameter and actuation forces required was also presented.

Megan Grimm, A. Antonio Arroyo, Michael Nechyba [3] introduce the thing which is a robotic hand with three digits, a pronating opposable thumb, and a 2 D.O.F. wrist. designed to more accurately model of human hand positioning and grasping capabilities than previous models, Thing is controlled by a flex-sensor-equipped glove

which relays the user's finger positions by means of flex sensors. It will also, by the time of publication, incorporate an image-processing system for determination of wrist posture.

The proposed design in this research is using an artificial muscle wire (Shape-Memory-Alloy SMA) as an actuator. Muscle wires belong to a class of metal alloys displaying a property called Shape memory Effect (SME), and when heated they will recover their original, shorter length and contract with a usable amount of force in the process [4]. The connection of muscle wires mechanically in parallel as proposed in this research makes the increment of the amount of force without affecting the amount of contraction possible and this help in the application of the robotics hand to catching different things without problem association.

2. The Proposed Technique of Catchment

There is a very different and much newer way to create motion from by using Shape Memory Alloys (SMA). These special metals undergo changes in shape when heated or cooled and do so with great force. The required gripper movements are ensured from the different activations of the connected muscle wires in series as shown in Figure [1].

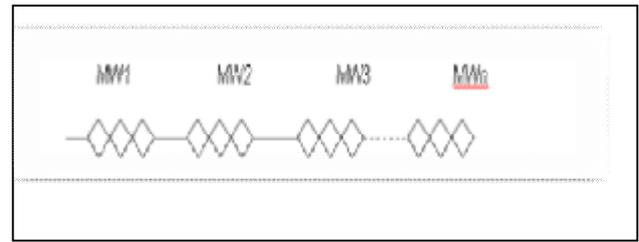


Fig.1. Schematic of MWs Connection in Series [5].

The important part of this job is the limitation of the amount of the catching force; that is the hand to catch different things without slipping or destroying them. The selection of the amount of the force depends on the size (cross section) of the used muscle wire and the type of the alloy that this muscle wire is made of, where each size and type give an absolute amount of force [4].

But if it is needed to control or select the desired amount of catching force to catch the present piece or particle, the number of parallel (mechanically) muscle wires of the same size and type or different must be selected and the process of selection must be through a control strategy. The proposed hands' actuator consists of two levels; level(1) is responsible of the required hands' tips motions, and level(2) works as a generator that generates the required amount of grasping force as shown in Figure [2].

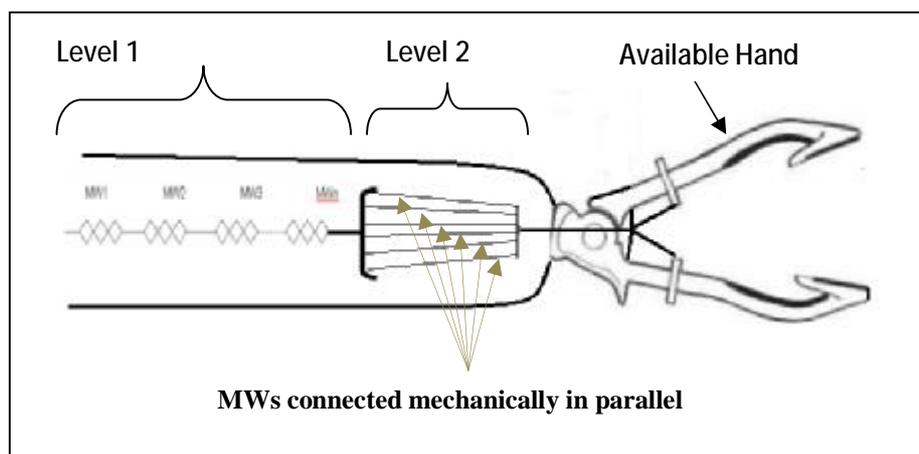


Fig.2. The Proposed Robotics Hand.

The Mechanical and Electrical characteristics of the used SMA are:

1. Type: Flexinol 375 HT
2. Diameter: 375 μm
3. Activation Temp: 90°C
4. Resistance: 8 Ω/m
5. Recommended Current: 2750 mA
6. Rec. Recovery Force: 2000 grams
7. Rec. Deformation Force: 393 grams
8. Rec. Deformation: 3-5%

The characteristics and dimensions of the used robotic hand

1. Stainless Steel Prostheses partial hand
2. Single degree of freedom hand
3. Two fingered
4. Length: 10 cm
5. Wight: 100 grams
6. Approximate Fingers cross section: 0.05 cm² each

3. Control Strategy

The pieces weight, size, and the coefficient of friction between the piece and the finger tip are all unknowns to the robot; therefore, the robot controller must take this into account, where the robotic hand should catch any piece without the need to know the preceding parameters. It is important also to know that the dropping of the piece results from not enough catching force to prevent slipping of the piece. Figure [3] indicates the robotics hand catching a piece [6].

From figure [3], to ensure catching the piece, the total friction force (2FF) must equal the value of the piece weight [6]:

From the Free-Body-Diagram (FBD) shown in figure [3.b]

$$2F_F = W$$

$$2\mu F_g = W$$

Where;

- μ = coefficient of friction.
- F_g = pressing force (grasping force).

W = piece weight.

So the grasping force F_g will be:

$$F_g = \frac{W}{2\mu}$$

The two parameters (μ , W) upon them the grasping force depends are unknowns; therefore, the required grasping force is also unknown. The best control strategy to decide the grasping force value in a manner like the human brain does is the fuzzy control strategy that mimics the human reasoning way [6].

The proposed fuzzy control in this research consists of three membership functions shown in figure [4], the inputs (amount of sliding (S) in (cm) and the rate of sliding (ΔS) in (cm/sec)) that may be observed from the slide sensor [6] and one output (number of the mentioned parallel connected muscle wires that will be activated to generate the required grasping force).

The rules of the fuzzy controller are designed as shown in Table (1).

From Table (1) because the variables are fuzzy, each rule (which is common sense selected) will contribute to a different degree. The first step toward arriving at a single output value is to compute the compatibility for each rule [7]. Where the compatibility is simply the product of the two probabilities in the rule (i.e. the influence of the rule):

$$\text{Compatibility} = w_i = A_{i1} \times A_{i2} \quad i = 1, 2, 3, \dots$$

Where;

- w_i = the influence of the rule i
- A_{i1} = probability of first condition (S)
- A_{i2} = probability of second condition (ΔS)

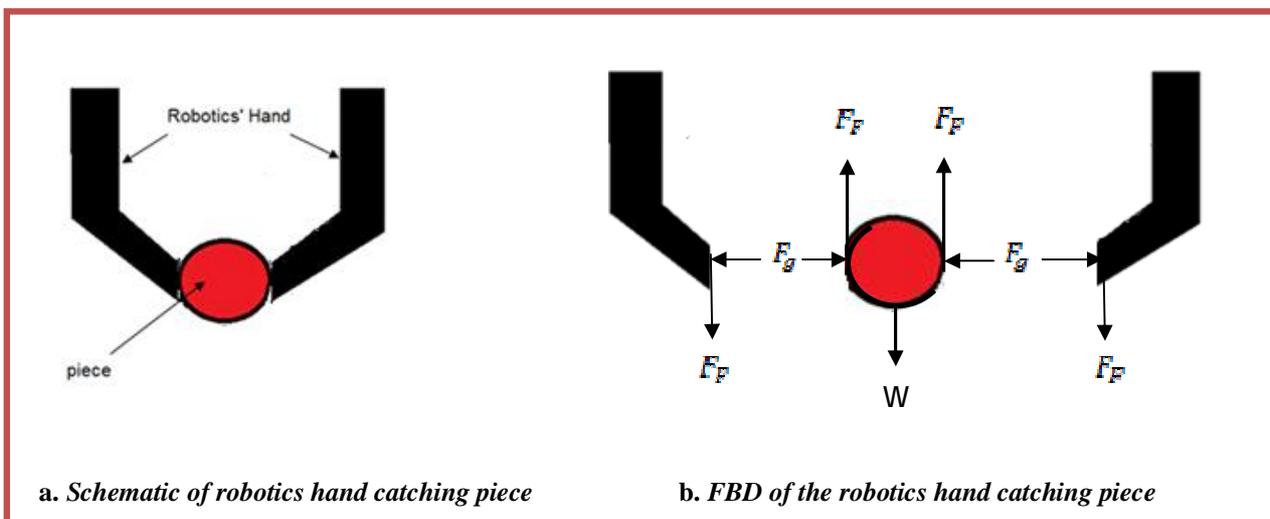


Fig.3. Robotics Hand Catching Piece [6].

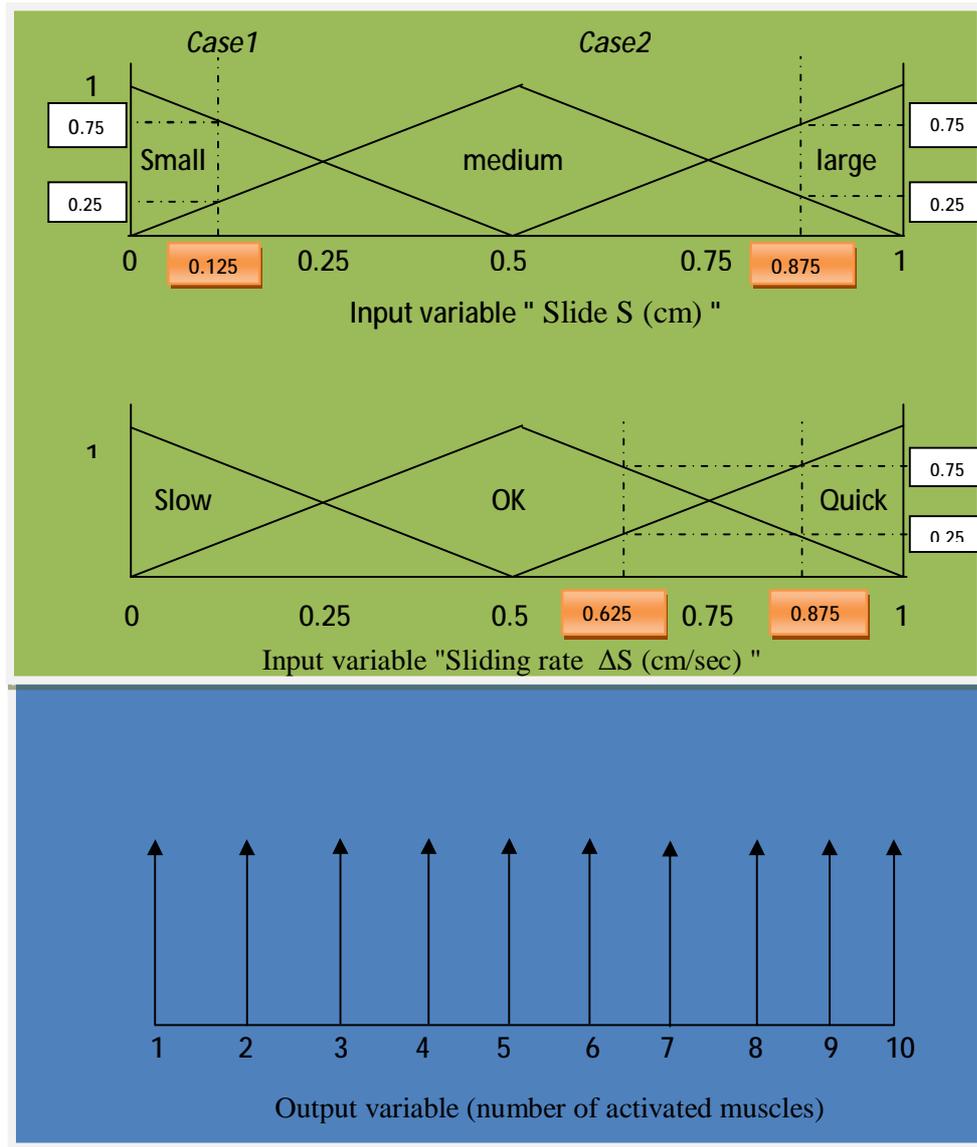


Fig.4. The Membership Functions of the Inputs and Output.

Table 1, Fuzzy Rules

ΔS	Slow	OK	Quick
Small	2	4	6
Medium	4	6	8
Large	6	8	10

For example take three case studies:

4. Results and Discussion

Case study 1: the slide $S=0.125$ cm and sliding rate $\Delta S = 0.625$ cm/sec shown in figure [4],

applying the compatibility to the applicable rules as following:

$$w1 = 0.75 \times 0.75 = 0.5625$$

$$w2 = 0.1875$$

$$w3 = 0.1875$$

$$w4 = 0.0625$$

Now the output value for each applicable rule is:

$$\text{Output} = y_i = w_i \times B_i \quad i = 1, 2, 3, \dots$$

Where

B_i = appropriate value from the output table

$$y1 = w1 \times B1 = 0.5625 \times 4 = 2.25$$

$$y2 = 1.125$$

$$y3 = 1.125$$

$$y4 = 0.5$$

Now there are two outputs from the two rules, but it is needed to defuzzify this data into a single

command for the number of the selected activated muscle wires and this is as follows [7]:

$$Y_{tot} = \frac{w_1y_1 + w_2y_2 + w_3y_3 + w_4y_4}{w_1 + w_2 + w_3 + w_4}$$

$$= 1.72 \approx 2 \text{ active muscle wires}$$

Case Study2: by increasing the amount of sliding say $S = 0.875$ cm with the same sliding rate $\Delta S = 0.625$ cm/sec, and by applying the same strategy as the first case:

$$w_1 = 0.1875$$

$$w_2 = 0.0625$$

$$w_3 = 0.5625$$

$$w_4 = 0.1875$$

and the output value for each applicable rule:

$$y_1 = 1.125$$

$$y_2 = 0.5$$

$$y_3 = 4.5$$

$$y_4 = 1.625$$

the value of output (i.e. number of activated muscle wires) will be:

$$Y_{tot} = \frac{w_1y_1 + w_2y_2 + w_3y_3 + w_4y_4}{w_1 + w_2 + w_3 + w_4} = 3.07$$

$$\approx 3 \text{ active muscle wires}$$

Case Study3: the sliding $S = 0.875$ cm and increasing the sliding rate $\Delta S = 0.875$ cm/sec. By applying the compatibility to the applicable rules as follows:

$$w_1 = 0.0625$$

$$w_2 = 0.1875$$

$$w_3 = 0.1875$$

$$w_4 = 0.5625$$

The output value for each applicable rule is:

$$y_1 = 0.375$$

$$y_2 = 1.5$$

$$y_3 = 1.5$$

$$y_4 = 5.625$$

the value of output (i.e. number of activated muscle wires) will be:

$$Y_{tot} = \frac{w_1y_1 + w_2y_2 + w_3y_3 + w_4y_4}{w_1 + w_2 + w_3 + w_4}$$

$$= 3.75 \approx 4 \text{ active muscle wires}$$

It is clearly shown from the results that by applying the proposed fuzzy control strategy to the proposed robotics hand, the process looks like that of the human hand whereas the slipping or the slipping rate of the caught piece increases and then the number of the activated muscle wires will

increase also to increase the amount of the catching force. This is what will happen when somebody needs to catch something he doesn't know the amount of its weight or the coefficient of friction between the hand finger tips and the caught piece.

5. Conclusion and Recommendation

The proposed control system with its easy way can simply mimics the human hand response from reducing the weight of the system and keeping away from the electrical noises and also the catching force can be developed in a small environment depending on the muscle wire specifications. So the whole system may be used effectively in many different applications like a robotic hand disassembling explosives or reaching different dangerous chemical parts without destroying them or slipping them down. It is also recommended in this work to design an effective sliding sensor that can measure the amount of sliding and at the same time the sliding rate.

6. References

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التحكم الضبابي بقوة مسك يد الإنسان الآلي باستخدام مشغل الأسلاك العضلية

يعرب عمر ناجي العزاوي

قسم هندسة الميكاترونكس/كلية الهندسة الخوارزمي/جامعة بغداد

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