PNEUMATIC ACTUATION AND FUZZY CONTROL OF ROBOTICS HAND

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ABSTRACT

In this research a robotic hand is proposed and controlled by simulation with fuzzy control technology, and that's in order to mimics the catching way of a human hand. The aim of this idea is to accomplish a dangers works that human person cannot or it is difficult to do it. The actuator that is used to provide the hand motion and grasping force is the proposed Pneumatic actuator associated with the artificial hand. Three case studies are established to indicate the ability of the control technique to achieve the requirements of catching. No phalanxes are observed in this hand.

Keywords: pneumatic Actuator, fuzzy control, robotic hand

التشغيل والسيطرة لزراع انسان ألي

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قسم الميكانيك

الخلاصة:

في هذا البحث تم اقتراح يد انسان الي وتم التحكم بها من خلال المحاكات باستخدام تقنية السيطرة الضبابية، وذلك من اجل محاكاة طريقة المسك لليد البشرية. الهدف من هذه الفكرة هو لانجاز الاعمال الخطرة التي لايمكن للانسان ان يقوم بها او من الصعوبة ان ينجزها. المشغل المستخدم لتحريك اليد وتوليد قوة المسك هو مشغل هوائي يكون مرافق لليد الاصطناعية. تم عمل ثلاثة دراسات حالة لإثبات امكانية تقنية السيطرة لتحقيق متطلبات المسك. لا توجد اية سلاميات في هذه اليد.

INTRODUCTION:

Much work over the recent years has been involved in the creation of a humanoid hand**.** Several forms of actuation have been used in these hands such as electrical revolute motors, DC motors, pneumatic actuators, pneumatic muscles and Shape Memory Alloy (SMA) muscle wires. The actuator that is used in this research is pneumatic actuator, where it is very important to understand that the motion of the robotics hand as it is required from the actuator, is not enough to be like that of humans', but at the same time the grasping force required to catch different things. And this is the idea of this research.

Lillian Y. Chang and Yoky Matsuoka [1] , presented thumb kinematics model that unifies several studies from biomechanical literature. They also validated the functional consistency (i.e. the nonlinear moment arm values) between the cadaveric data and the ACT thumb. This functional consistency preserves the geometric relationship between muscle length and joint angles, which allows robotic actuators to imitate human muscle functionality

Tetsuya Mouri , etal [2] ,presented a newly developed anthropomorphic robot hand called KH Hand type S, which has a high potential of dexterous manipulation and displaying hand shape, and its master slave system using the bilateral controller for five-fingers robot hand. The robot hand was improved by reducing the weight, the backlash of transmission, and the friction between gears by using elastic body.

A. H. Arieta1, etal, [3], described an electrically powered prosthetic system controlled by electromyography (EMG) signal detected from the skin surface of the human body. The research of electrically powered prosthetic systems is divided into two main subjects. One is the design of the joint mechanism. It is proposed the use of an adaptive joint mechanism based on the tendon-driven architecture. This mechanism includes mechanical torque-velocity converters and a mechanism to help the proximal joint torque by distal actuators. The other subject is the recognition of the EMG signal. For the discrimination of many patterns and nonlinear properties of the EMG signal, a controller based on a simple pattern recognition information process is proposed. The system also drives 12 servomotors to move the adaptive joint mechanism.

Kenji KANEKO, etal [4], presented a development of multi-fingered hand, which is modularized and can be attached to life-size humanoid robots. The developed hand has a four fingers with 17 joints, which consist of 13 active joints and 4 linked joints. A miniaturized 6-axes force sensor is newly developed and is mounted on each fingertip for improving the manipulability. A main node controller with I/O, motor drivers, and amplifiers for 6-axes force sensors are also newly developed.

IKuo etal [5] developed a robot hand having equal number of DOF to human hand was driven by a new method using ultrasonic motors and elastic element. The method uses restoring force of elastic element as driving power for grasping an object, so that the hand can perform the soft and stable grasping motion with no power supply. In addition, all the components are placed inside the hand It had equal number of joints and DOF to human index finger, and it was also equal in size to the finger of average adult male. The performance of the robot finger was confirmed by fundamental driving test.

Jessica Lauren Banks [6] investigated the problem of a tactile sensing platform for anthropomorphic manipulation research through the fabrication and simple control of a planar 2-DOF robotic finger inspired by anatomic consistency, self-containment, and adaptability. The robot was equipped with a tactile sensor array based on optical transducer technology whereby localized changes in light intensity within an illuminated foam substrate corresponds to the distribution and magnitude of forces applied to the sensor surface plane. The integration of tactile perception was a key component in realizing robotic systems which organically interact with the world. Such natural behavior was characterized by compliant performance that could start internal, and respond to external, force application in a dynamic environment. However, most of the current manipulators that support some form of hap tic feedback either solely derive proprioceptive sensation or only limit tactile sensors to the mechanical fingertips.

Peter Scarfe and Euan Lindsay [7] presented the design and implementation of a low-cost air muscle actuated humanoid hand developed at Curtin University of technology. This hand offers 10 individually controllable degrees of freedom ranging from the elbow to the fingers, with overall control handled through a computer GUI. The hand was actuated through 20 McKibben-style air muscles, each supplied by a pneumatic pressure-balancing valve that allows for proportional control to be achieved with simple and inexpensive components. The hand was successfully able to perform several human-equivalent tasks, such as grasping and relocating objects.

THEORETICAL WORK:

There are two important parameters as mentioned associated with the robotics hand (motion, and grasping force). The motion can be easily accomplished using an available hand (in the markets) with a built in DC- motor as shown in **Figure (1).**

Actuator:

The amount of grasping force (Fg) that must be applied depends on the type of the material that the caught piece was made of. Where it is known the grasping force of eggs for example differs from that of steel rod. Therefore the amount of force that must be controlled is depending on the caught piece material.
Since the robot do not have any idea about the part or piece it want to catch, so it will not be able to decide the amount of grasping force without a sensing element.
Hence here in this research it is proposed an idea of sensing element that will be responsible on sensing the amount of grasping force indirectly and then making the controller through suitable actuator decide the desired grasping. Now look to the free- body- diagram of the robotics hand shown in **Figure (2)**. Statically from the free-body-diagram of **Figure (2):**

$$aF_p = bF_g \qquad (1)$$

$$F_g = \frac{a}{b}F_p \qquad (2)$$

For the pneumatic cylinder of **Figure (3)**:

$$F_p = P_pA \qquad (3)$$

Substituting equation (3) into equation (2) result:

$$\therefore \boldsymbol{F_g = \frac{a}{b} A\, P_p} \quad (4)$$

Where a, b, and A are constants dimensions and that at the time of starting grasp (i.e. the end effecter is in touch with the piece, therefore it is assuming very small motion and may be negligible). From equation (4) it is clearly shown that the control of the grasping force (Fg) depends on the controlled pressure (Pp) of the pneumatic cylinder.

The pressure control of the cylinder may be possible by using a pneumatic valve with controllable release port. **Figure (4)** shows a schematic of a general pneumatic solenoid directional valve.

The pneumatic valve with its simplest form consists of three openings (i/p, o/p, and release ports). To control the amount of the outlet pressure Pp, it may be possible by setting the spring to a desired amount, and this may be manually or automatically.

Control Strategy:

Presetting the spring force to its initial minimum value (Fin) as shown in the **Figure (5)** where:

$$\boldsymbol{F_{in} = k_1\, x_1} \quad (5)$$

As the value of cylinder pneumatic Force (Fr) reaches the value of (Fin) then the relief spring will start move and open the relief valve and so makes setting to the cylinder pressure Pp.

$$F_{in} = F_r$$

$$P_r A_1 = k_1 x_1$$

$$\boldsymbol{x_1 = \frac{A_1}{k_1} P_p} \quad (6)$$

Using equation (6) to decide the value of x1 (spring setting) depending on the required outlet pressure Pp.

From equation (4)

$$P_p = \frac{b}{aA} F_g \tag{7}$$

Substitute equation (7) into equation (6) gives:

$$x_1 = \frac{A_1}{k_1} \frac{b}{aA} F_g \tag{8}$$

From equation (8) A1, A, a, b, and k1 are constants (at the time of grasping). So the equation (8) is a direct relationship between required grasping force Fg and spring displacement x1.

Since it is unknown what part or piece that the robotics' hand will catch, this initiates a problem to the proposed hand derive. As a proposed technique to decide a grasp force necessary for catching any part, it is very important to understand that the part with its grasping force do not slide with robotics' hand fingers and so thinking that a sliding sensor putted on the effective side of the hand in which the catch process occur. The technique involves initialize a setting force with its minimum value then checking if the sliding still occur between the caught piece and the robotics' hand then increase the value of the grasping force amount through an actuator which is responsible on increasing/decreasing the spring displacement of the release port and continue with this process until the sliding stops and hence catch occur. Now in order to understand the catching process, look to **Figure (6)**.

From the **Figure (6),** to ensure catching the piece, the friction force (FF) must equal the value of the piece weight as following:

$$2F_F = W$$

$$2\mu F_g = W \tag{9}$$

Where μ = coefficient of friction.

Fg = pressing force (grasping force).

W = piece weight.

From equation (9), the grasping force Fg will be:

$$F_g = \frac{W}{\mu} \quad (10)$$

Equation (10) indicates two uncertainties (μ, W) upon them the grasping force depends, and therefore the robot does not have any idea as mentioned about the piece it will catch and this means that the grasping force Fg is also uncertainty value.

The control strategy can be indicated by the simply Fuzzy control system shown in the **Figure (7)**.

From **Figure (7),** the Fuzzy controller is of two inputs (amount of sliding (S) in (cm) and the rate of sliding (ΔS) in (cm/sec)) that may be gotten from the slide sensor and one output (the amount of release spring displacement x1 in (cm)). The membership functions of the inputs and output are shown in **Figure (8)** and without taking the dimensions into account for simplicity. The rules of the fuzzy system are shown in the **Table (1).**

RESULTS AND DISCUSSION:

Depending on the proposed membership functions taking for example slide S=0.2cm and sliding rate ΔS= 0.5cm/sec, and therefore for the proposed fuzzy rules the output (i.e. spring displacement x1) = 0.354cm, and as a comparison if the rate of sliding increases to ΔS=0.8cm with the same sliding S=0.2cm, the output will increase x1=0.5cm/sec to an amount nearly same as increment in ΔS.

Another case is approximately large sliding S=0.8cm and small sliding rate ΔS=0.1cm/sec, and the output x1=0.451. So the proposed fuzzy control strategy is possible and applicable.

CONCLUSION:

After obtaining the results and discuss it, it is clearly shown that it is possible to use the robotic hand in catching different parts and each as force required to couch it without destroy or slip it and that through using pneumatic system simply controlled and it is possible to develop it through dealing with the modern control systems. Only one problem associated with the pneumatic system is the large consumption of the air.

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Table (1) fuzzy rules

S \ ΔS	Small	Medium	Large
Small	Small	small	medium
Medium	Medium	small	medium
Large	Medium	large	large

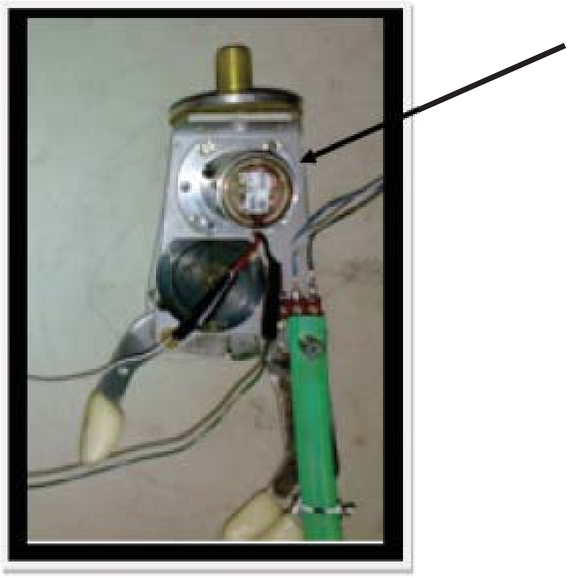


Figure (1). The Robotics Hand with its deriving DC-motor

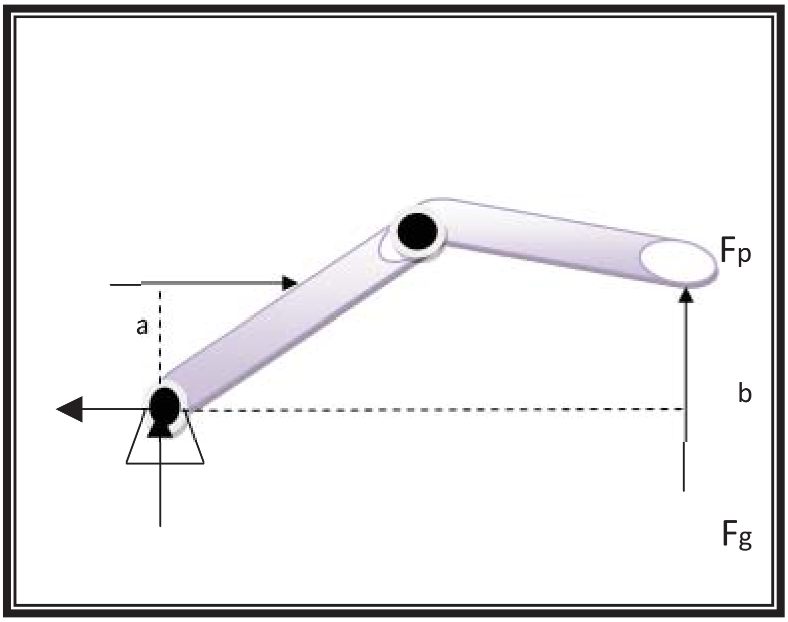


Figure (2) free- body- diagram of the robotics hand

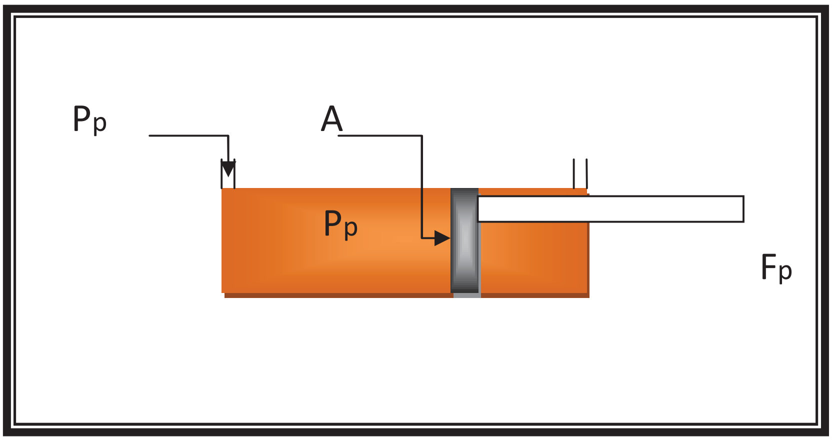


Figure (3) pneumatic cylinder

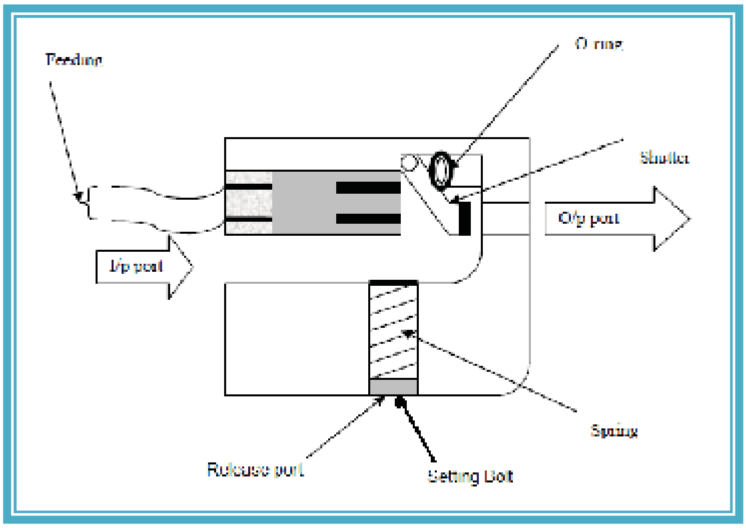


Figure (4) schematic of the pneumatic solenoid valve

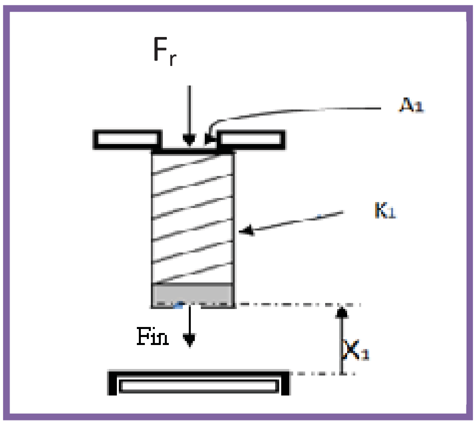


Figure (5) the spring setting of the release port

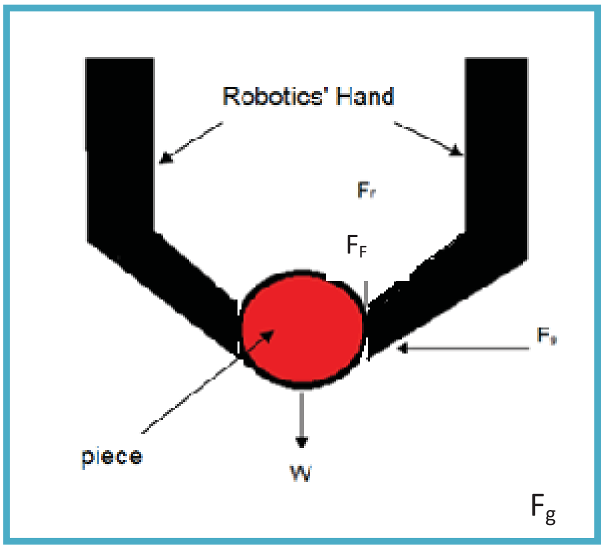


Figure (6) robotics' hand catching piece

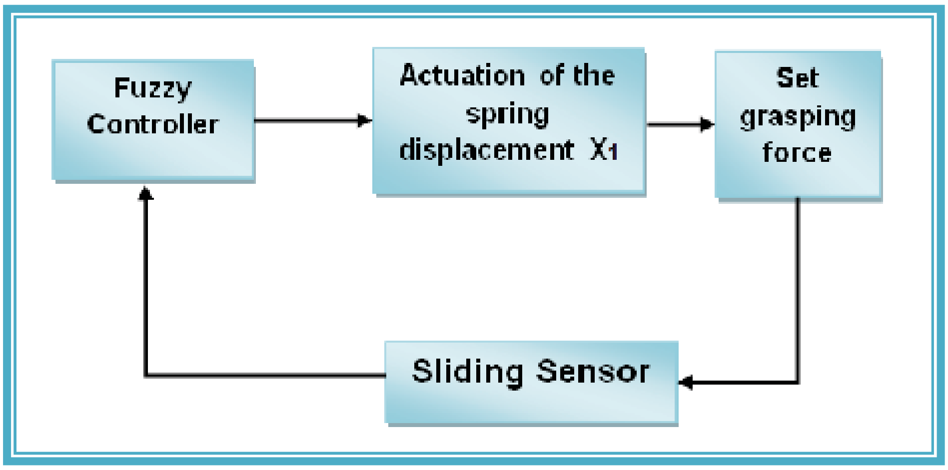


Figure (7) Fuzzy control system

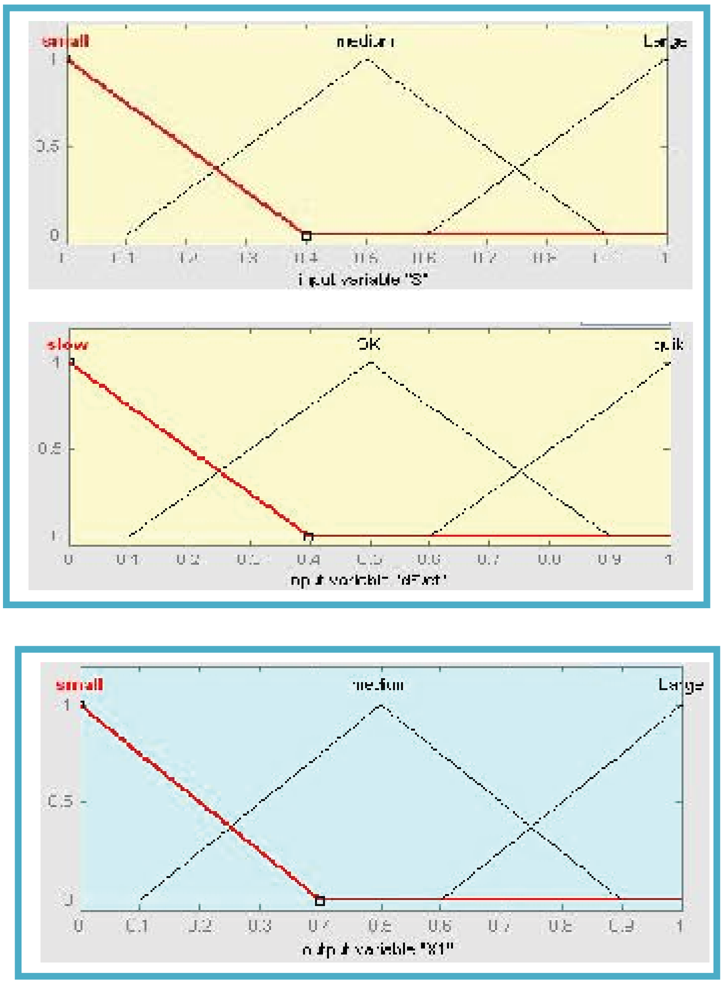
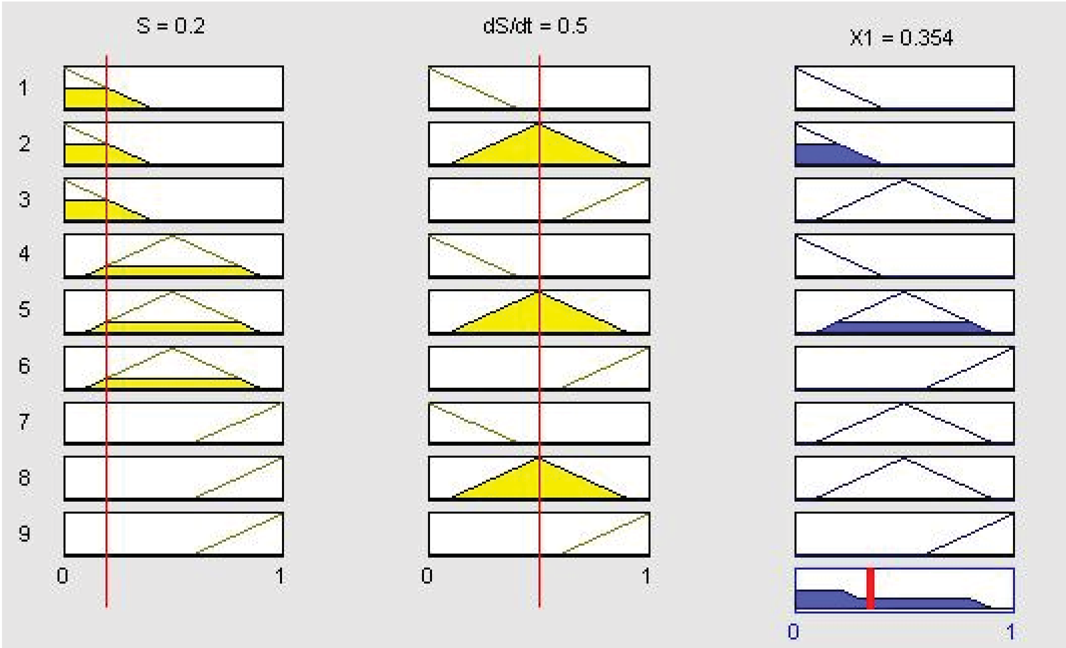
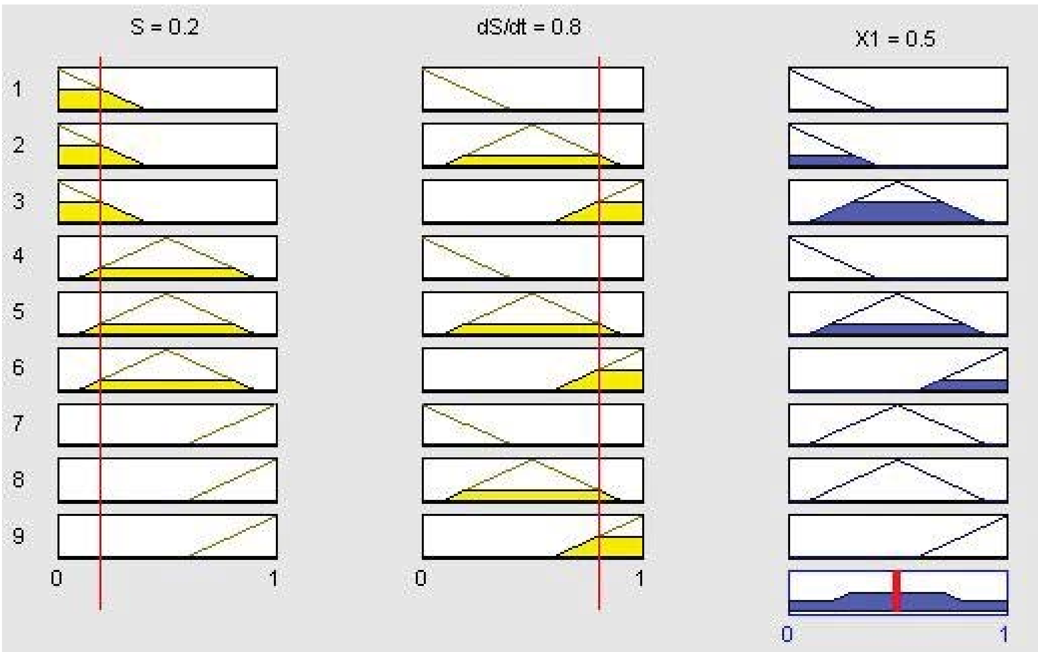
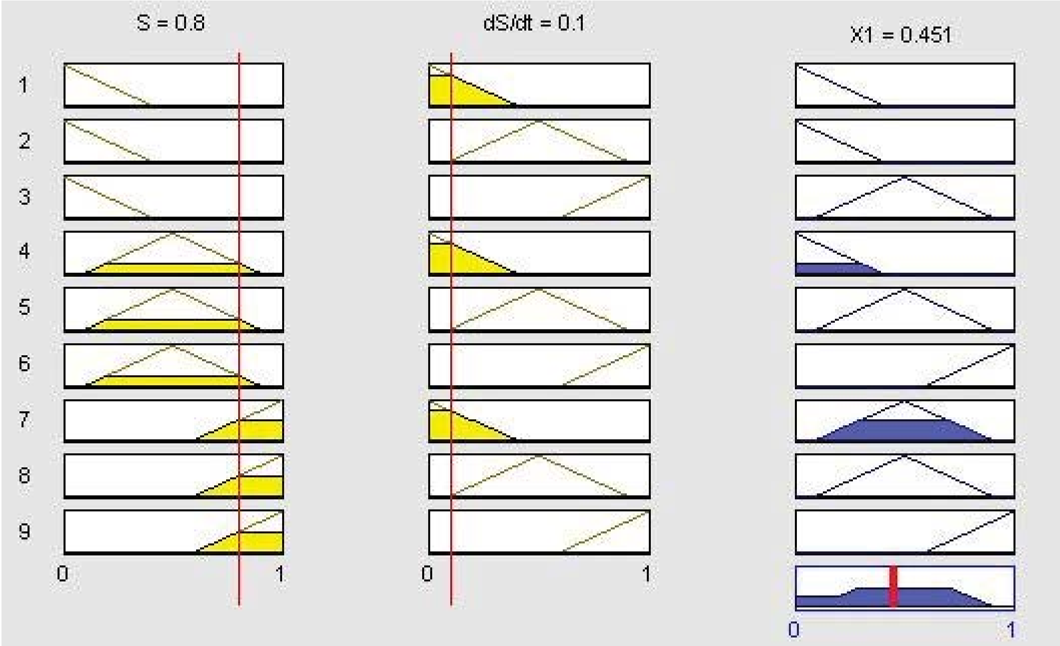


Figure (8) The membership functions of the inputs and output


S = 0.2
dS/dt = 0.5
X1 = 0.354
1
2
3
4
5
6
7
8
9
0
1
0
1
0
1


S = 0.2
dS/dt = 0.8
X1 = 0.5
1
2
3
4
5
6
7
8
9
0
1
0
1
0
1


S = 0.8
dS/dt = 0.1
X1 = 0.451
1
2
3
4
5
6
7
8
9
0
1
0
1
0
1