Fuzzy Control Algorithm Implementation using LabWindows

MARIUS CONSTANTIN POPESCU, ANCA PETRISOR, ADRIAN DRIGHICIU, RADUCU PETRISOR
Faculty for Engineering in Electromechanics, Environment and Industrial Informatics
University of Craiova
Decebal Bv, No.107, 200440, Craiova
ROMANIA
mrpopescu@em.ucv.ro, apetrisor@em.ucv.ro, adrighiciu@em.ucv.ro, raducu_petrisor@elprest.ro

Abstract: - This paper presents the way to create a fuzzy controller used to command a fluid flow servo-valve with force reaction, this servo-valve being the execution element of an industrial robot adaptation system which adjusts the position on one axel. Practically, beginning from a value of the reference (the position in which we wish to move the free extremity of the hydraulic cylinder's piston's cane), for example at half the distance the piston covers and at a value of the speed with which the piston moves at a certain moment, the paper goes through all the stages of fuzzy algorithm and a firm value of the command which the controller produces in this case. The spread of the applications' field of the numerical systems for adjustment and control of the technological processes is, obviously, sustained by the superior performances achieved by such systems, as is the case of the fuzzy system, comparing to the conventional analogical automated systems.

Key-Words: - fuzzy algorithm, servo-valve, industrial robot, implementation, LabWindows environment

1 Introduction

In an advanced industrialized society the modern technology supposes the complex automation of the productive processes based on the use of the artificial intelligence. The increase of the nomenclature of the created pieces and the decrease of the relative rate of the bulk and serial production because of the small serial production and unique production leads to new automation means.

If the conventional conveyors created for a single goal can't efficiently solve this problem, the industrial robots are the ones which resolve it.

In the last years, a significant increase of the number of various fuzzy applications has been notice. Applications of this type have extended upon different domains that use robots [1], such as: hi-tech filming devices (photo and recording cameras), washing machines, micro wave devices, and also upon the industrial control systems and the high performance medical instruments.

The industrial robots are general electro-pneumatic-hydrokinetic systems having more degrees of freedom, able to perform handling operations independently and automatically under the control of a command system equipped with a programming memory [2].

Including of a microprocessor in a control and measure system gives the opportunity that the manoeuvres of the operator to be taken by the microprocessor and additionally to obtain some important advantages:

- The taking over of the operator commands such as zero adjust and scale adjustment, the scale selection assuring a plus of accuracy and safety in exploitation [3], [4].
- Self-calibration and automatic equalization of the effect of the climate factors. Also are calculated the errors and the final result of the measurement is corrected.
- The improvement of the accuracy by abstraction the systematic errors (by self-calibration, self-correction).
- The decrease of the system components numbers by removing the components for the implementation of the hardware control.
- The increase of the versatility of the apparatus by obtaining some additional possibilities of measure based on the internal programs.
- The increase of the working speed by automation the measuring operations [5].
- The possibility of estimation by calculus of the other signal parameters (peak value, mean value, effective value, the calculus of the distortions, of the amplitudes spectrum, the estimation of the phase, the estimation of the phase difference).
- The possibility of self-testing by special programs performed by the incorporated microprocessor at the operator command or in case of appearance some functional anomaly. In this case

can be unleashed a testing and signalling procedure of the eventually faults [6].

All these advantages clearly show that the modern control and measure systems can not exist without being controlled by microprocessors.

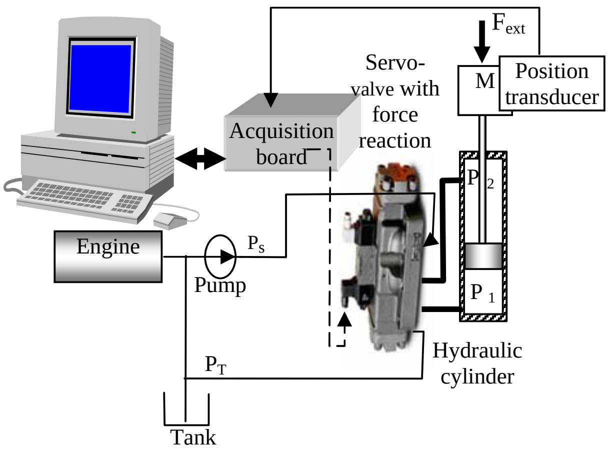


Fig.1 The functional scheme of the designed experimental system

The experimental model (fig. 1) designed to observe the ways in which a fluid flow servo-valve with force reaction can be controlled, is a one axel positioning system.

The used servo-valve is one of the 72 series, built by MOOG and is voltage controlled (-10÷+10 Vcc), with 300Ω resistance at the command coil.

The hydraulic cylinder with double effect has a distance of 250mm for the piston to cover and piston's diameter of 60mm.

The position transducer WE used is a resistive transducer (multiple shift potentiometer), and consists of a system which converts the translation movement of the piston into a rotation movement which is transferred directly to the potentiometer.

ATMEL offers a wide range of microcontrollers. A part of the devices have the advantage of a high speed of the nucleus which double the frequency of the internal clock for CPU. Also includes products with specific applications with special functions for using on the specialized markets: NAC network, MP3 applications [7].

ATMEL offers microcontrollers on 8/18 bits based on a strong architecture. The devices ATMEL do not need special knowledge of programming. So, they open the way to a much largest class of potential users. They are relatively a few input/output lines, a limited instructions set and almost without peripherals are convenient for control applications.

The control of the process is made with the help of the computer through an acquisition and control board which is based on a ATMEL 89C52 microcontroller, and which communicates with the calculus system though the serial port [8].

The acquisition system has: an analogical input to read the potentiometer, an analogical output for the numerical-analogical converter which controls the servo-valve and a serial communication channel for the connection with the computer.

2 Technical Characteristics of the Robot

The technical characteristics of the industrial robot include: the dimensions, the values of the workable displacements, the accuracy, the repeatability, the numbers of degrees of freedom, the action time, the robot weight, the volume of the working space, the capacity of the command and control system, the speed, the transportable load, the working conditions, the possibility to dispose of more working arms [9], [10].

In general, the performances of the industrial robots can be appreciated using global parameters defined as it follows:

- the global parameter k_1, characterizes the industrial robot from the point of view of its efficiency of interfering in the industrial environment and of its suppleness [11]:

$$k_1 = \frac{\text{The\_volume\_of\_the\_working\_space } (m^3)}{\text{The\_duty\_weight\_of\_the\_robot } (N)} \quad (1)$$

- the global parameter k_2, characterizes the industrial robot regarding the specific gravitational capacity of handling

$$k_2 = \frac{\text{The\_weight\_of\_the\_handled\_object } (N)}{\text{The\_duty\_weight\_of\_the\_robot } (N)} \quad (2)$$

- the global parameter k_3, characterizes the technical qualities of the industrial robot, these being better as k_3 is bigger

$$k_3 = \frac{\text{The\_volume\_of\_the\_working\_space } (m^3)}{\text{The\_duty\_weight\_of\_the\_robot } (N)} \text{x}$$

$$\text{x} \frac{\text{The\_weight\_of\_the\_handled\_object } (N)}{\text{The\_positioning\_precision } (\mu m)} \quad (3)$$

3 Boards for data acquisition and control

A practical possibility much used in the building of an acquisition and control system is that of using the acquisition boards together with the adequate software, as it is shown in figure 2.

The acquisition boards are process interfaces having both acquisition functions and functions of processing and outside remittance of the signals generated by the computer. They involve all or only a part of the up presented systems together with additional functions [12], [13].

Because a good part of the computerized measure systems problems is represented by the aspects regarding to the remittance and processing of the information contained in digital signals, one of the known classifications of these systems is in accordance with the protocol used for the remittance of the digital signals.

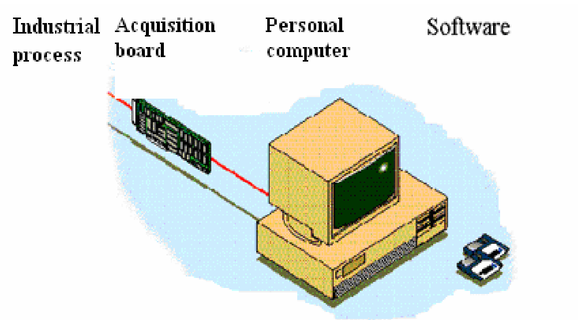


Fig.2 The use of the acquisition boards in processes control

The control and acquisition systems (CAS) that can be used in robots control are:
- CAS with serial communication appeared at once with the idea of using the computer
- CAS with parallel communication which have a similar structure to those with a serial communication, the main difference consist of the protocol used for remittance the information.
- CAS with data acquisition boards that are characterized, first of all, by the fact that the conversion operation of the information signal from analogical into digital form and vice-versa is not made by the analogical measure device but by a different electronic component (data acquisition board) fitted in computer.

4 Design of the Fuzzy Controller Choosing the Linguistic Variables and Terms

In the fuzzyification process of certain information (fuzzy controller input information) are necessary the following steps:
- to define the base set (the universe of discourse) which characterized the linguistic variable: the base set defines the variation domain of the certain information;
- to define the linguistic terms which characterized the certain information; this means to define the membership function;
- to establish the membership degree of the certain value at defined linguistic.

To adjust the position of the cylinder's piston, three linguistic variables, associated to the input quantities (position error and movement speed of the piston) and output quantities (command) are defined:

- the position error – an input linguistic variable which varies between [emin ÷ emax] mm;

- the movement speed of piston – the second input linguistic variable which calculates as the ratio of the distance between two successive readings of the position transducer and the time between the two readings, with values in the interval [vmin ÷ vmax] mm/s;

- the command – output linguistic variable which varies between [Umin ÷Umax].

The variation domain of the output (command) is considered in unities of the numeric-analogical converter (NAC) MAX 536, used for the command of the servo-valve. This is a converter on 12 bits with differential output (-2,5 ÷ +2,5), the domain in which the command of the fuzzy regulator varies is (0 ÷ 4096). So:
- when a 0 command is desired, the number of NAC must be 2048;
- when a (-2,5 ÷ 0)V command is desired, the number of NAC unities must be between (0 ÷ 2048);
- when a (0 ÷+2,5)V command is desired, the number of NAC unities must be between (2048÷ 4096).

It follows a vague representation of the position error for the variation domain [emin ÷ emax] mm and of the movement speed of the piston for the [vmin ÷ vmax] mm/s domain, through the affiliated functions and a vague representation of the command for the [Umin÷Umax] domain.

The linguistic variables position error may be vaguely characterized through the following linguistic terms [2]:
εMn – high negative position error - with the affiliation function:

$$\mu\varepsilon Mn=(emin, emin, eMn, ezen) \quad (4)$$

εmdn – medium negative position error - with the affiliation function:

$$\mu\varepsilon mdn=(eMn, emdn, 0) \quad (5)$$

εze – zero position error - with the affiliation function:

$$\mu\varepsilon ze=(ezen, 0, ezep) \quad (6)$$

εmdp – medium positive position error - with the affiliation function:

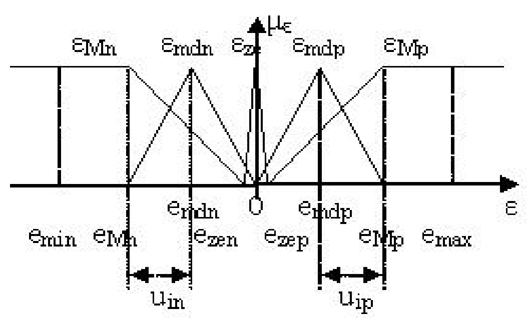
$$\mu\varepsilon mdp=(0, emdp, eMp) \quad (7)$$

εMp – high positive position error - with the affiliation function:

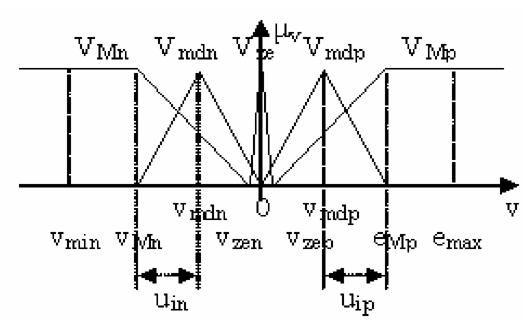
$$\mu\varepsilon Mp=(ezep, eMp, emax, emax) \quad (8)$$

where e_{min}, e_{max}, e_{zen} and e_{zep} are given as initial data, and other parameters are to be calculated for generality with the following relations:

$$u_{ip} = e_{max}/3;\ u_{in} = e_{min}/3;\ e_{min} = -250;\ e_{max} = 250;$$
$$e_{Man} = 2^* u_{ip};\ e_{mnd} = u_{in};\ e_{mdp} = u_{ip}; \quad (9)$$
$$e_{Map} = 2^* u_{ip};\ e_{zen} = -100;\ e_{zep} = 100;$$



a)



b)

Fig.3 The shape of the affiliated functions for the linguistic variables:
position error and speed of piston

As it is observed in fig. 3a and b, for the linguistic variables: position error and movement speed of the piston, the shapes of the affiliated functions afferent to the linguistic terms e_{Mn}, v_{Mn}, e_{Mp}, v_{Mp}, is like a trapeze, and for the linguistic terms e_{mdn}, v_{mdn}, e_{ze}, v_{ze}, e_{mdp} and v_{mdp} is triangular symmetric.

Linguistic variable speed of movement of the piston can be vaguely characterized through the following linguistic terms [3]:
v_{Mn} – high negative speed with the affiliated trapeze function:

$$\mu_{vMn} = (v_{min}, v_{min}, v_{Man}, v_{zen}) \quad (10)$$

v_{mdn} – medium negative speed with the affiliated triangular function:

$$\mu_{vmdn} = (v_{Man}, v_{mdn}, 0) \quad (11)$$

v_{ze} – zero speed with the affiliated triangular function :

$$\mu_{vze} = (v_{zen}, 0, v_{zep}) \quad (12)$$

v_{mdp} – zero speed with the affiliated triangular function:

$$\mu_{vmdp} = (0, v_{mdp}, v_{Map}) \quad (13)$$

v_{Mp} – the high positive speed with the affiliated trapeze function:

$$\mu_{vMp} = (v_{zep}, v_{Map}, v_{max}, v_{max}) \quad (14)$$

To represent vaguely the linguistic variable speed of movement for the piston, are adopted the following calculus relations:

$$u_{ip} = v_{max}/3;\ u_{in} = v_{min}/3;\ v_{min} = -100;\ v_{max} = 100;$$
$$v_{Man} = 2^* u_{ip};\ v_{mnd} = u_{in};\ v_{mdp} = u_{ip}; \quad (15)$$
$$v_{Map} = 2^* u_{ip};\ v_{zen} = -40;\ v_{zep} = 40;$$

The linguistic variable command can be vaguely characterized through the following linguistic terms:
U_{M_n} – high negative command with the affiliated trapeze function:

$$\mu_{UM-n} = (u_{min}, u_{min}, u_{Man}, u_{mdn}) \quad (16)$$

U_{md-n} – medium negative command with the affiliated triangular function:

$$\mu_{Umd-n} = (u_{Man}, u_{mdn}, u_{zen}) \quad (17)$$

U_{m-n} – low negative command with the affiliated triangular function:

$$\mu_{Um-n} = (u_{mdn}, u_{minn}, 0) \quad (18)$$

U_0 – zero command with the affiliated triangular function:

$$\mu_{U0} = (u_{zen}, 0, u_{zep}) \quad (19)$$

U_{m-p} – low positive command with the affiliated triangular function:

$$\mu_{Um-p} = (0, u_{minp}, u_{mdp}) \quad (20)$$

U_{md-p} – medium positive command with the affiliated triangular function:

$$\mu_{Umd-p} = (u_{zep}, u_{mdp}, u_{Map}) \quad (21)$$

U_{M-p} – high positive command with the affiliated trapeze function:

$$\mu_{UM-p} = (u_{mdp}, u_{Map}, u_{max}, u_{max}) \quad (22)$$

To represent vaguely the linguistic variable command, are adopted the following calculus relations:

$u_{min}= 0;$

$u_{max}= 4096;$

$u_{zen}= 2000; u_{zep}= 2096;$

$u_{in}= (u_{zen} – u_{min})/3;$

$u_{minp}=2048+ (u_{mdp} - 2048)/2;$

$u_{minn}= 2048- (u_{mdp} - 2048)/2 ;$

$u_{mdp}=2048+ u_{zep} + u_{in};$

$u_{mdn}=2048- u_{zen} - u_{in}; u_{Mp}= 2048+u_{zep} + 2*u_{in};$

$u_{Mn}= 2048-u_{zep} + 2*u_{in};$ (23)

The shape of the affiliated functions afferent to the linguistic terms U_{M-n} and U_{M-p} is a trapeze, while the one of the U_{md-n}, U_{m-n}, U_{m-p}, U_{md-p} and U_0 are triangular symmetric as seen in fig. 4.

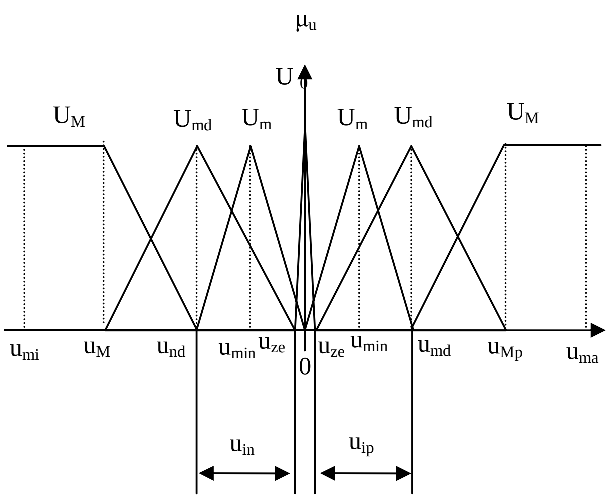


Fig.4 The shape of the affiliated functions for the linguistic variable command

When the base of rules is built, following are taken into account:

- the number of sequences of the base of rules (not to mistake the number of sequences with the number of rules) is equal to the number of linguistic terms of the input linguistic variable position error;
- we continue to consider that the position reference is situated at the half of the piston distance to cover;
- we consider the high positive position error when the piston is retired into the cylinder;
- we consider the zero position error when the piston is close to the half of the distance;
- we consider the high negative position error when the piston almost got out the cylinder;
- the speed is positive when the piston moves to right (forward move) and negative when it moves to left (withdraw move);
- the command can be low, medium and high in a positive way when the piston goes forward, so that its speed to become positive, low, medium and high in a negative way when the piston retreats, and zero command when the piston doesn't move.

Taking into account the considerations above the whole resulted base of rules is [4]:

R1: If (ε_{Mn} and v_{Mn}) then U_{M_n};
R2: If (ε_{Mn} and v_{mdn}) then U_{M_n};
R3: If (ε_{Mn} and v_{ze}) then U_{M_n};
R4: If (ε_{Mn} and v_{mdp}) then U_{M_n};
R5: If (ε_{Mn} and v_{Mp}) then U_{M_n};
R6: If (ε_{mdn} and v_{Mn}) then U_{md_n};
R7: If (ε_{mdn} and v_{mdn}) then U_{md_n};
R8: If (ε_{mdn} and v_{ze}) then U_{md_n};
R9: If (ε_{mdn} and v_{mdp}) then U_{M_n};
R10: If (ε_{mdn} and v_{Mp}) then U_{M_n};
R11: If (ε_{ze} and v_{Mn}) then U_{m_n};
R12: If (ε_{ze} and v_{mdn}) then U_{m_n};
R13: If (ε_{ze} and v_{ze}) then U_0;
R14: If (ε_{ze} and v_{mdp}) then U_{m_p};
R15: If (ε_{ze} and v_{Mp}) then U_{md_p};
R16: If (ε_{mdp} and v_{Mn}) then U_{md_p};
R17: If (ε_{mdp} and v_{mdn}) then U_{md_p};
R18: If (ε_{mdp} and v_{ze}) then U_{md_p};
R19: If (ε_{mdp} and v_{mdp}) then U_{md_p};
R20: If (ε_{mdp} and v_{Mp}) then U_{m_p};
R21: If (ε_{Mp} and v_{Mn}) then U_{M_p};
R22: If (ε_{Mp} and v_{mdn}) then U_{M_p};
R23: If (ε_{Mp} and v_{ze}) then U_{M_p};
R24: If (ε_{Mp} and v_{mdp}) then U_{M_p};
R25: If (ε_{Mp} and v_{Mp}) then U_{M_p};

For another value of the reference, the basis of rules will have to be modified accordingly, in order for that a new sequence of the basis of rules to be evaluated function of the value. To reduce the complexity of this algorithm, we'll consider the reference at half the distance between min and max.

5 Evaluation of the If …Then Rules

The vague inference is the algorithm after which the implications IF (premise) – THEN (conclusion), reunited in a base of rules, are evaluated. In the evaluation of the inference the MAX – MIN, MAX – PROD or SUM-PROD compositions are used [5].

To understand the inference mechanism which is the base of a fuzzy regulator, the following case study is considered: at a certain moment, the position error has the value 125 and the movement speed of the piston is 25 mm/s.

To determine the affiliation degrees of these firm quantities at the corresponding linguistic terms, the affiliated functions of triangular and trapeze type are used [6].

The afferent value of the affiliation degrees of firm quantities ε=125 to defined linguistic terms are according to relation (20).

$$\varepsilon_0 = \{0, 0, 0, 0.5, 0.37\} \qquad (24)$$

Proceeding in the same way for calculation of affiliation degrees of firm quantities v=25 of piston movement speed, this are according to relation (21).

$$v_0 = \{0, 0, 0.37, 0.75, 0\} \qquad (25)$$

In any τ moment, fuzzy algorithm activate rules from BRF (as parallel process). The output of each fuzzy rule is a fuzzy value, which result from basic operations in fuzzy logic. Therefore each rule from BRF represent a logic expression realized with conjunction AND operator.

Thereafter we apply AND operation of fuzzy sets, after that on output we obtain a punctual minimum of affiliation functions from entire definition domain of output variables.

So, for a rule from BRF with form:

R1: If (ε_{Mn} and v_{Mn}) then U_{M_n}

we have:

$$\omega U_{M\_n} = \text{MIN}(0, 0) = 0; \qquad (26)$$

where:

ωU_{M_n} – is activation scalar value of fuzzy set U_{M_n}.

So this is a rule which won't use because the activation scalar value of fuzzy set U_{M_n} of output variable is zero.

Follow up we retain only the useful rules for the supposed numeric case which are 4.

R18: If (ε_{mdp} and v_{ze}) then U_{md_p}

For this rule the activation scalar value is:

$$\omega_{Umd\_p} = \text{MIN}(0.5, 0.37) = 0.37; \qquad (27)$$

R19: If (ε_{mdp} and v_{mdp}) then U_{md_p}

For this rule the activation scalar value is:

$$\omega_{Umd\_p} = \text{MIN}(0.5, 0.75) = 0.5; \qquad (28)$$

R23: If (ε_{Mp} and v_{ze}) then U_{M_p}

For this rule the activation scalar value is:

$$\omega_{UM\_p} = \text{MIN}(0.37, 0.37) = 0.37; \qquad (29)$$

R24: If (ε_{Mp} and v_{mdp}) then U_{M_p}

For this rule the activation scalar value is:

$$\omega_{UM\_p} = \text{MIN}(0.5, 0.75) = 0.5; \qquad (30)$$

We remark that in inference process the rules can have like result the same output fuzzy set, in generally activated by the different ω_i coefficients. This is the case of rules R18 and R19 from this example which have the output fuzzy set the command $\mathbf{U_{md\_p}}$, respectively R23 and R24 which have the output fuzzy set the command $\mathbf{U_{M\_p}}$. Thereafter, the inference operation is analyzed on the entire level of BRF through a composition technique of the elementary inferences results (from each i rule activated).

In this case we use the composition method noted as MAX, according whom the rules which have the same output fuzzy set, this (output fuzzy set) is activated (ponderate) with the maximum value of ω_i coefficient.

Therefore the rules R18 and R19 the output fuzzy set U_{md_p} will be ponderated with ωU_{md_p} coefficient calculated in this way:

$$\omega U_{md\_p} = \text{MAX}(\omega_{18}, \omega_{19}) = \text{MAX}(0.37, 0.5) = 0.5 \qquad (31)$$

respectively for the rules R23 and R24, the output fuzzy set U_{M_p} will be ponderated with ωU_{M_p} coefficient calculated in this way:

$$\omega U_{M\_p} = \text{MAX}(\omega_{23}, \omega_{24}) = \text{MAX}(0.37, 0.5) = 0.5 \qquad (32)$$

The form of each activate fuzzy set from entire domain of output variable, depends on used "coding" diagram.

We will use a coding process with correlation by product, according to the fuzzy output of the system result by the multiplication of the affiliation functions of the output variable, with activation scalar value of i referred rule [7].

For supposed example the fuzzy output of the system is:

$$0 = \text{MAX}(\omega_{18}, \omega_{19}) m_{Umd\_p} + \text{MAX}(\omega_{23}, \omega_{24}) \cdot m_{UM\_p} \qquad (33)$$

which geometrical is summarized to the reunion of determinate areas by fuzzy sets resulted from coding, figure 5.

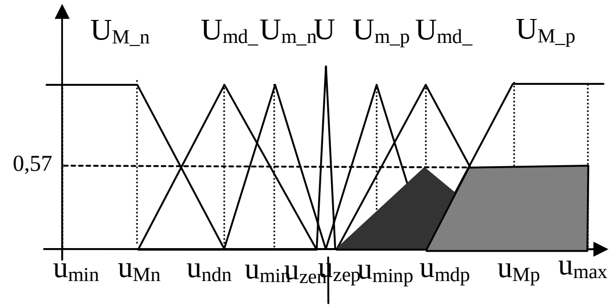


Fig. 5 Output fuzzy set

6 Unfuzzying vague information

In this application we opted for the most used method of unfuzzying, which offer the most consistent results, *the weight center method (centroid)*. According with this, if output fuzzy sets are determinate by the inference method with product correlation, then we may calculate global weight center from local weight centers of each i rule from BRF, as:

$$u_k = \frac{\omega_{U_{M\_n}} I_{U_{M\_n}} c_{U_{M\_n}} + \omega_{U_{md\_n}} I_{U_{md\_n}} c_{U_{md\_n}} + \ldots}{\omega_{U_{M\_n}} I_{U_{M\_n}} + \omega_{U_{md\_p}} I_{U_{md\_p}} + \ldots + \omega_{U_{M\_p}} I_{U_{M\_p}}} =$$

$$\frac{\ldots + \omega_{U_{M\_p}} I_{U_{M\_p}} c_{U_{M\_p}}}{\omega_{U_{M\_n}} I_{U_{M\_n}} + \omega_{U_{md\_p}} I_{U_{md\_p}} + \ldots + \omega_{U_{M\_p}} I_{U_{M\_p}}} \qquad (34)$$

where:
ω_i is activation scalar value of i rule from BRF;
I_i is surface area (triangle area or trapezoidal area);
c_i is the ordinate of weight center of output fuzzy set fit to i rule.
For this numeric case the value of output is:

$$u_k = \frac{\omega_{U_{md\_p}} I_{U_{md\_p}} c_{U_{md\_p}} + \omega_{U_{M\_p}} I_{U_{M\_p}} c_{U_{M\_p}}}{\omega_{U_{md\_p}} I_{U_{md\_p}} + \omega_{U_{M\_p}} I_{U_{M\_p}}} =$$

$$= \frac{0.5 \times 333.3 \times 2762.2 + 0.5 \times 583.2 \times 3620}{0.5 \times 333.3 + 0.5 \times 583.2} = 3095.9 \qquad (35)$$

Because the number obtained is a real number and digital – to – analogical converter work only with integers, the value 3095.9 is rounded to proximate integer, that is 3096. In figure 5 is represented the command interface of the experimental system implemented in LabWindows CVI. On this interface can observe the shape of the real response of positional system to few variation of position reference transducer.

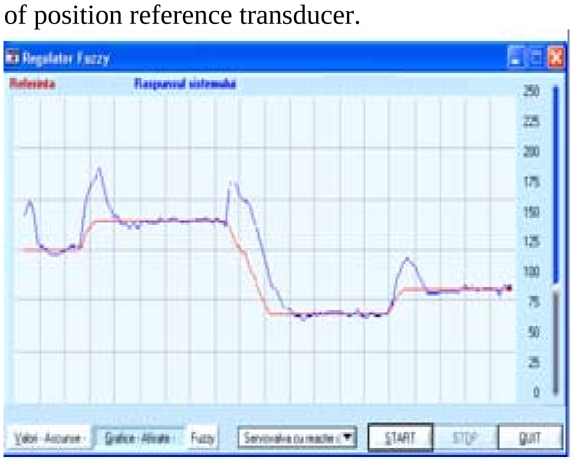


Fig. 6 The command interface of the experimental system

7 ATMEL reception

The ASM program for microcontroller reception [9], [10] is:

```
; Control reception from master
;Verify the correctness of the first byte
SERVICE:CLR  ES; Infirm the serial interruption
CLR  EA;
   NOP ; data reception
   PUSH  ACC; salve the  accumulator
   PUSH  PSW
   CLR  PSW.3 ;RS0=0
 SETB  PSW.4 ;RS1=1 ,
   MOV  R4,#5;load the data number to be received
   MOV R1,#DATE_RX; load the data address to be
received
   MOV A,#00H;
   MOV @R1,A; cancellation PREVIOUS value
   INC  R1;
   MOV @R1,A; cancellation PREVIOUS value
   INC  R1;
   MOV  @R1,A; cancellation PREVIOUS value
   INC  R1;
   MOV @R1,A; cancellation PREVIOUS value
   INC  R1;
   MOV  @R1,A; cancellation PREVIOUS value
   MOV  R1,#DATE_RX ; load the data address to
be received
DA_REC: MOV @R1,SBUF    ; read the received
value
   INC  R1 ; Increment the data saving adress
   CLR  RI ;Delete the reception flag
   DJNZ  R4,NU_ENDRX;Number of saved data
   LJMP  REC_OK
; Wait the reception of another byte
NU_ENDRX:NOP
   CLR  TR0 ; Stop timer 0
   MOV  TH0,#064H ; timer for 10ms
   MOV  TL0,#00H        ;for waiting reception
   SETB  TR0 ; starting timer 0 for 10 ms
   CLR  TF0 ; Delete the timer indicator
ETY_REC:JB  RI,DA_REC;a new reception?
```

```
  JNB  TF0,ETY_REC ;without reception in 10 ms
  LJMP  COM_BAD;
; Verify corectness + CRC
REC_OK: CLR  TR0
  MOV  R1,#DATE_RX ; load the data address to be delivered
  MOV  REC1,@R1;Save data
  INC  R1 ; load the data address to be delivered
  MOV  REC2,@R1; Save data
  INC  R1 ; load the data address to be delivered
  MOV  REC3,@R1; Save data
  INC  R1 ; load the data address to be delivered
  MOV  REC4,@R1; Save data
  INC  R1 ; load the data address to be delivered
  MOV  REC5,@R1; Save data
; Verify CRC
  MOV  A,REC1; load with the first byte
  ADD  A,REC2; add the second byte
  ADD  A,REC3; add the third byte
  ADD  A,REC4; add the fourth byte
; CJNE    A,REC5,COM_BAD;compared to the fourth
  MOV  A,REC5; load with the first byte
  CJNE  A,#32H,COM_BAD    ;compared with the fifth
;Verify the header of the data package
  MOV  A,REC1; load with the first byte
  CJNE  A,#'V',COM_BAD; Failed communication
;verify the second data byte
  MOV  A,REC2; load with the second byte
  ANL  A,#01111111B;
  MOV  REC2,A;
  CLR  C          ;delete carry
  SUBB           A,#100; subtraction A-100
  JC  REC2_OK ;
  MOV  REC2,#100 ;if A>100 =>A=100
REC2_OK:MOV    IMP_TOT,REC2;    Save    the impulse period
;verify the third data byte
  MOV  A,REC3; load with the third byte
  ANL  A,#01111111B;
  MOV  REC3,A;
  CLR  C           ;Delete carry
  SUBB           A,IMP_TOT; subtraction  A-100
  JC  REC3_OK;
  MOV  REC3,IMP_TOT ;if A>100 =>A=100
REC3_OK:MOV   IMP_M1,REc3;save the impulse time
MOV  A,IMP_TOT;A=NT IMP TOTAL
  CLR  C         ; Delete carry
  SUBB           A,IMP_M1; subtraction A-IMP_M2
 MOV  IMP_M1,A;Save NO. OF IMPULS ON 0
; verify the fourth data byte
  MOV  A,REC4;load with  the fourth data byte
  MOV  C,ACC.7;load the working sense
  MOV  SENS_M2,C; load the working sense
  ANL  A,#01111111B;
  MOV  REC4,A;
  CLR  C         ; delete carry
  SUBB  A,IMP_TOT; subtraction A-100
  JC REC4_OK;
  MOV REC4,IMP_TOT ;if A>100 =>A=100
REC4_OK:MOV IMP_M2,REC4; save the impulse time
  MOV A,IMP_TOT ;A=NT IMP TOTAL
  CLR C            ;Delete carry
  SUBB A,IMP_M2 ; subtraction A-IMP_M2
 MOV IMP_M2,A ; Save NO. OF IMPULS ON 0
;All the bytes are verified =>everything is OK
SETB RX_OK   ;RECEPTION OK
 MOV TXD1,#'R' ;Load delivered data
 MOV TXD2,#'O' ;Load delivered data
  MOV TXD3,#'K' ;Load delivered data
  MOV TXD4,#0DH ; Load delivered data
LJMP TX_DATE ;DELIVERED DATA
;Error communication
COM_BAD:CLR  RX_OK  ;ERROR  RECEPTION
MOV TXD1,#'E' ; Load delivered data
  MOV TXD2,#'R' ; Load delivered data
  MOV TXD3,#'R'; Load delivered data
  MOV TXD4,#0DH ; Load delivered data
  LJMP TX_DATE ;DELIVERENCE DATA;-------
```

```
TX_DATE:NOP
  SETBTI ;For fuctioning with breaking
  MOV CRC,#00H ; initialization for CRC calculus
  MOV TEMP,TXD1 ;load TXD1
TX_CRC TEMP;deliver TXD1
MOV TEMP,TXD2 ;load TXD2
TX_CRC TEMP;deliver TXD2
MOV TEMP,TXD3 ;load TXD3
TX_CRC TEMP;deliver TXD3
MOV  TEMP,TXD4 ;load TXD4
TX_CRC TEMP;deliver TXD4
TX_CRC CRC;TX CRC
JNB  TI,$ ;waiting delivery CRC   CLR  TI ; Delete transmission flag  CLR  RI ; Delete reception flag
 CLR  PSW.3  ;RS0=0
CLR  PSW.4 ;RS1=0 ,
  POP  PSW
  POP  ACC;
  SETB  ES
  SETB  EA
  RETI ; come back from the serial breaking.
```

8 Industrial robots programming in LabWindows/CVI environment

LabWindows/CVI is an environment for developing new applications using the programming language ANSI C. It is ideal for industrial automation, measurements and offers the possibility to store process data. The debugger offers the possibility to import the Borland C++ Builder 4.0 and Visual C++ 6.0 libraries and generate the code of the design interface.

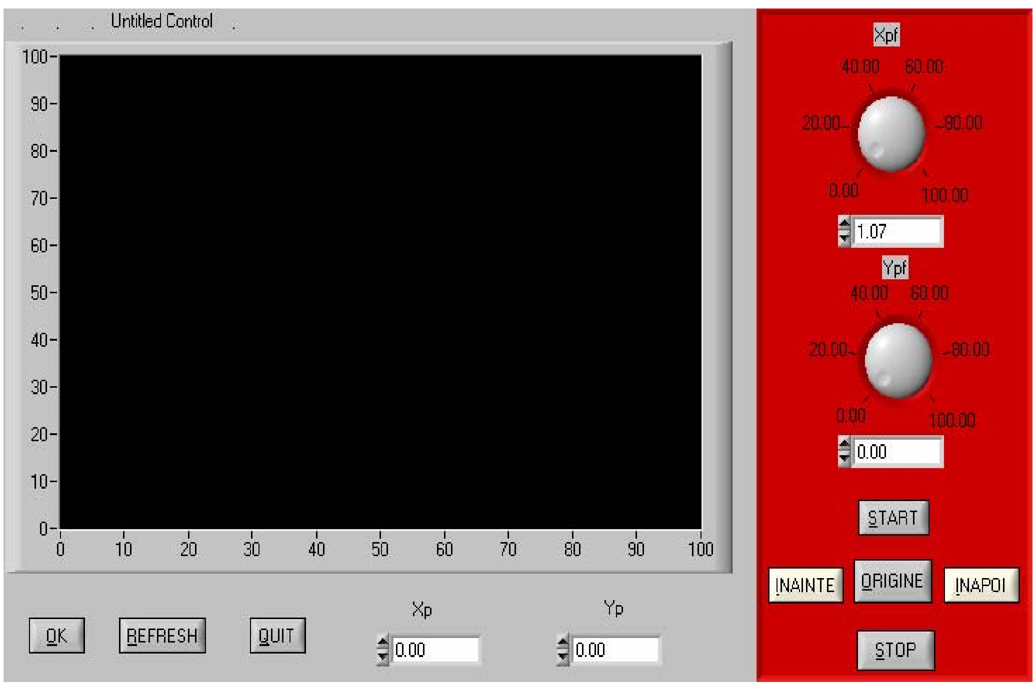


Fig. 7 The interface created with LabWindows environment

9 Conclusion

Fuzzy control algorithm implemented in this example with LabWindows/CVI software offers betters performances so in transitory condition and in the stationary condition than classic PID algorithm (this is based on practice) being visible the fuzzy control anticipation effect of next evolution of the piston. The advantage comes even from capability to modify the variation interval of linguistic defined terms, the capability offered by relations (9), (15), (23).

References:

[1] Ivanescu. M., *Sisteme avansate de conducere în robotica*, Scrisul Românesc Publishing, Craiova, 2003.

[2] Sofron, E., Bizon, N., Ionita, S., Radian, R. (1998) *Sisteme de control fuzzy. Modelare si proiectare asistatã de calculator*, ALL Publishing,, Bucuresti.

[3] Preitl, St., Precup, E. *Introducere în conducerea fuzzy a proceselor*, Technical Publishing, Bucuresti. pp.89-101, 1995.

[4] Popescu M.C., *Modelarea si simularea proceselor*, Universitaria Publishing, Craiova, pp. 499- 523, 2008

[5] Popescu M.C., *Comanda si optimizarea proceselor*, Universitaria Publishing Craiova, pp. 268- 276, 2007.

[6] Popescu M.C., *Inteligenta artificiala*, Constantin Brâncusi Publishing Tg. Jiu, pp. 115-127, 1999.

[7] Popescu M.C., Hybrid neural network for prediction of process parameters in injection moulding, *Annals of University of Petrosani, Electrical Engineering*, Universitas Publishing House Petrosani, Vol. 9, pp. 312-319, 2007

[8] Popescu M.C., Ilie B., Popescu L., Onisifor O. Simulation Hybrid Fuzzy Control of SCARA Robot, *Proceedings of the 3rd WSEAS International Conference on Applied and Theoretical Mechanics*, pg. 175-181, Puerto De La Cruz, Tenerife, 2007.

[9] Popescu M.C., *Telecomunicații*, Editura Universitaria Craiova, 2008.

[10] Petrişor A., Bizdoacă N.G., Drighiciu M., Popescu M.C., Control Strategy of a 3-DOF Walking Robot, *The International Conference on „Computer as a Tool*”, pp.2337-2342,1-4244-0813-X/IEEE, Warsaw, Polonia, 9-12, sept. 2007.

[11] Popescu M. C, Petrişor A., 2D Optimal Control Algorithms implementation, *WSEAS Transactions on Systems and Control Journal*, Issue 1, Vol. 1, Nov. 2006, pp.84-93, ISSN 1991-8763.

[12] Bizdoaca N.G, Petrisor A, Bizdoaca E., Conventional control and fuzzy control algorithms for shape memory alloy based tendons robotic structure, *WSEAS Transactions on Systems and Control Journal*, 2008.

[13] Petrişor A, Marin C, Bizdoaca N.G, Cazacu D, Variable Causality Dynamic System Approach for Robot Control, *WSEAS Transactions on Systems and Control Journal*, Issue 1, Volume 1, Nov. 2006, ISSN 1991-8763, pp.26-31.

[14] Petrişor A, s.a, Modeling and Simulation of Walking and Climbing Robots based on Stable States Transition Approach as Control Strategy, *Proceedings of the 12th WSEAS Int. Conf. SYSTEMS*, Heraklion, Greece, July 22-24, 2008, pp.216-221, ISBN: 978-960-6766-83-1, ISSN: 1790-2769.

[15] Popescu M.C.,sa, The Simulation Hybrid Fuzzy Control of Scara Robot, *WSEAS Transactions on Systems and Control Journal*, Issue 2, Volume 3, February 2008, pp.105-114, ISSN 1991-8763.