FUZZY ALGORITHM FOR PRESSURE CONTROL IN AN ENCLOSURE

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Abstract: This paper presents the design and implementation of a fuzzy control algorithm, for adjust the pressure in a enclosure. In the paper are presented characteristic stage for synthesis fuzzy algorithm (fuzzyfication of the ferm information, base rules building, the inference and composition of the rules, defuzzyfication), suitable for pressure control in a enclosure. Also, in the paper is presented a case study, an experimental results and a number of conclusions.

Keywords: fuzzy, rules, system, control

1. Presentation of the system

This paper presents the design of a fuzzy algorithm for pressure control in a enclosure. Block diagram of the pressure control system in an enclosure, which is tested the designed fuzzy algorithm, is shown in Fig. 1:

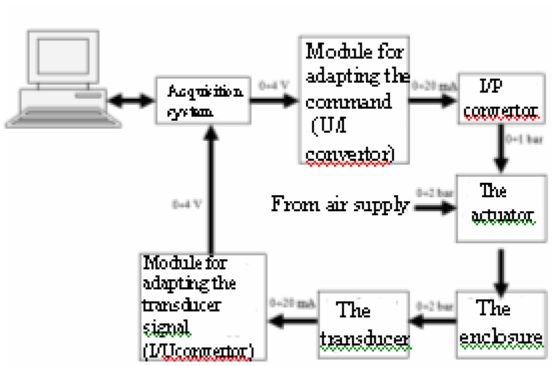

Fig. 1

Designed fuzzy control algorithm was software implemented using LabWindows CVI. The physical system used to tested the algorithms, is provided with a acquisition system through which we can acquire the value of pressure from enclosure, value which is read with a pressure transducer, and for transmission the command elaborated by the control algorithm to actuator system.

Because the information carrier signal at the output controller, is a electrical signal (0÷5V), and the command signal for actuator is a pressure (0÷1 bar), between the two elements mentioned above, is used a electropneumatic converter, type Masonailan. The input of the electropneumatic converter is a current in the range $4 \div 20$ mA. The output of the electropneumatic converter is in the range $0,2 \div 1$ bar.

The actuator used is a aerflow valve with membrane and resort with a maximum flow of 3.5 liter/min and a pressure for command in the range $0,2 \div 1$ bar .

The enclosure where is adjust the pressure has a volume of 15 liters. Adjustment range of pressure is in the range $0 \div 1,5$ bar.

The pressure transducer used is of type TP-01 with a measurement range $0 \div 6$ bar. Output signal of the transducer is a current in the range $4 \div 20$ mA, and the nominal voltage for the pressure transducer is 24 Vcc.

To convert the current of the output transducer ($4 \div 20$ mA) into a voltage (as required analog input of the acquisition system) with range 0÷4 V, between the pressure transducer and analog input of the acquisition system is interposed converter I/U.

The flow transducer used is a MEMS D6F-P type, with measuring range between $0 \div 6$ l/min. The output signal of the transducer is voltage in the range $0 \div 4$ VDC, the nominal supply voltage of the transducer is 10 VDC.

2.The synthesis of the fuzzy regulator

2.1. The fuzzyfication of the firm information and creating the rules base

We'll start to materialize a fuzzy regulator for adjusting the pressure in an enclosure. The nominal pressure in enclosure is 2 bars, and the domain for adjustment is 0÷1,5 bars.

For adjusting the pressure in an enclosure we'll define 3 linguistic variables, associated to the input variables (the pressure error and airflow) and to the output variable (the command):

- the pressure error, with variation between -1,5÷1,5bars;
- the airflow, which has values between 0÷7 liter/min;
- the command, which takes values between 0÷5 V.

The pressure error linguistic variable can be vaguely characterized through the following linguistic terms:

P_m–low pressure error with membership function: µPm= (-1.5, -1.5, -1, 0);

P_p–moderated pressure error with membership function: µPp= (-1, 0, 1);

P_M–high pressure error with membership function: µP_M= (0, 1, 1.5, 1.5).

The airflow linguistic variable can be vaguely characterized through the following linguistic terms:

Q_m–low airflow with membership function: µQm= (0, 0, 0.58, 1.7);

Q_p–moderated airflow with membership function: µQp= (0.58, 1.7, 2.86);

Q_M–high pressure error with membership function: µQ_M= (1.7, 2.86, 3.5, 3.5).

For the pressure error and airflow linguistic variables, the shape of the membership functions afferent is as shown in Fig. 2.

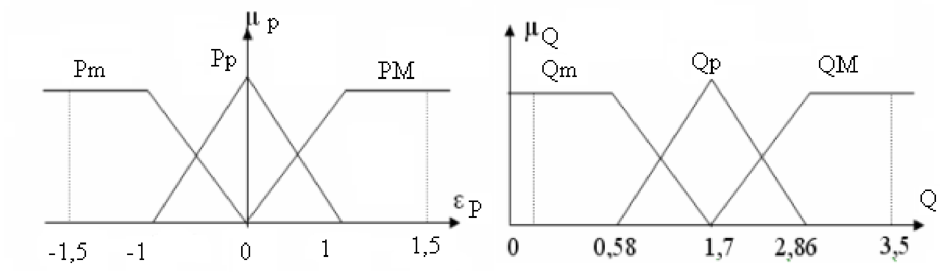

Fig.2.

For the command linguistic variable we'll consider 3 linguistic terms:
U_m – low command with the membership function: μ_{Um}= (0, 0, 2,5);
U_{md} – moderate command with the membership function: μ_{Umd}= (0, 2,5, 5);
U_M – high command with the membership function: μ_{UM}= (2,5, 5, 5).
Next will be exemplified the way to determine the membership function for a firm value (P= 0.7 bar). The pressure error at the initial moment is P_0=P-P_r=0.7-0=0.7. For this we will use the triangular and trapezoidal membership functions which have the following analytic expression[1]:

$$\mu(p_0) = \begin{cases} \frac{p_0 - A}{C - A} \text{ for } A \le p_0 \le C \\ 1 - \frac{p_0 - C}{B - C} \text{ for } C \le p_0 \le B \\ 0 \sim \text{otherwise} \end{cases} \quad (1)$$

$$\mu(p_0) = \begin{cases} 0 & \text{for } p_0 < A \\ \frac{p_0 - A}{B - A} & \text{for } A < p_0 \le B \\ 1 & \text{for } B < p_0 \le C \\ \frac{D - p_0}{D - C} & \text{for } C < p_0 \le D \\ 0 & \text{for } D < p_0 \end{cases} \quad (2)$$

The values of the membership function, corresponding for the firm value P_0=0.7 and having the defined linguistic terms, are:

P_0={$\mu_{Pm}(P_0)$, $\mu_{Pp}(P_0)$, $\mu_{pM}(P_0)$} (3)
We will calculate now the values of the membership function.
For the P_m linguistic term we have: $\mu_{Pm}(P_0)$.

P_0=0.7, A=-1.5, B=-1.5, C=-1, D=0 (4)
It results: P_0>D and so: μ_{Pm}(0.7)=0.
For the P_p linguistic term we have: $\mu_{Pp}(P_0)$.

P_0=0.7, A=-1, B=1, C=0 (5)

It results: C<P_0 ≤B and so: μ_{Pp}(0.7)=0.3.
For the P_M linguistic term we have: $\mu_{PM}(P_0)$.

P_0=0.7, A=0, B=1, C=1.5, D=1.5 (6)

It results: A<P_0 ≤B and so: μ_{PM}(0.7)=0.7.
According to the relation (3) we have the 3-ouple:

P_0 = {0, 0.3, 0.7 (7)

For the airflow fuzzy variable, the values of the membership function, corresponding for the firm values Q_0=0,82 liter/min and having the defined linguistic terms, are:

Q_0 = {0.785, 0.214, 0}. (8)

The rules base for the fuzzy regulator can be simple defined as follows:

R1: IF (p=Pm) AND (q=Qm) THEM (u=Um);
R2: IF (p=Pp) AND (q=Qm) THEM (u=Umd); (9)
.
R9: IF (p=PM) AND (q=QM) THEM (u=Umd).

2.2. The inference and composition of the rules

Each rule from the fuzzy rules base (BRF) represents a logical expression built with the conjunction operator AND. Therefor, the intersection operation of the fuzzy multitude is applied, obtaining at the output a punctual minimum of the membership function for whole domain of the output variables[1].
And so, for a rule from BRF as:

R8: IF (p=Pp) AND (q=QM) THEM (u=Umd); (10)

we have: ω_{Umd} = MIN (0.3, 0) = 0, where ω_{Umd} – is the scalar value for activating the fuzzy multitude U_{md}.
Further, from the whole BRF we retain only the useful rules (the significant rules) for the given numerical case, which are 4:

R2 → ω_{Umd} = MIN (0.3, 0.7) = 0.3
R3 → ω_{UM} = MIN (0.7, 0.7) = 0.7
R5 → ω_{Umd} = MIN (0.3, 0.2) = 0.2 (11)
R6 → ω_{Umd} = MIN (0.7, 0.2) = 0.2

We observe that in the inference process the rules may have as result the same fuzzy multitude as output, generally activated with different ω_i coefficients[1]. This is the case of rules R2, R5 and the R6 from the example we analyze. So, the operation of inference is finalized at the level of the whole BRF through a tehnicque of composition of the results of the elementary inferences. In our case, we adopt the method of composition known as MAX, after which the rules which have the same fuzzy multitude for output, it is activated with the maximum values of the coefficient ω_i[1]. So for the rules R2, R5, R6, the output fuzzy multitude U_{md} will be pondered with the coefficient ω_{Umd} calculated as follows:

$$\omega_{Umd} = MAX(\omega_2, \omega_5, \omega_6) = MAX(0.3, 0.2, 0.2) = 0.3 \quad (12)$$

Further in this example we applied the inference process with correlation through product, as is shown in the graphics in Fig. 3.

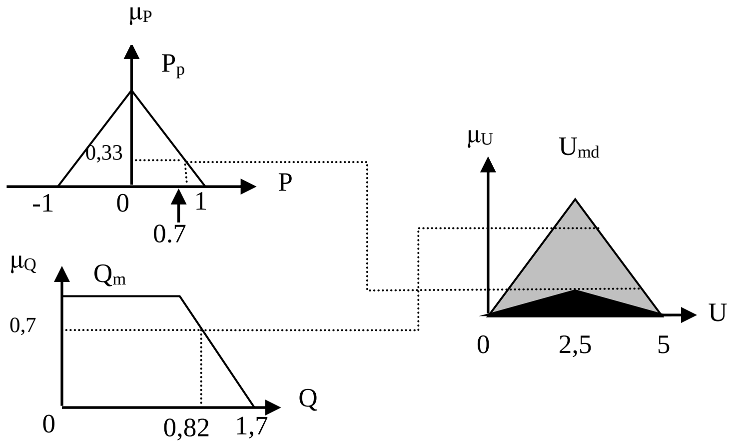

Fig. 3.

In the same way it is done the inference with correlation through product for the rules R3, R5 and R6.

For the studied example, the fuzzy output of the system is:

$$O = MAX(\omega_2, \omega_5, \omega_6) m_{Umd} + \omega_2 \cdot m_{UM} \quad (13)$$

which, geometrically speaking, sums up to the reunion of the surfaces limited by fuzzy multitudes as result of codification as in Fig. 4.

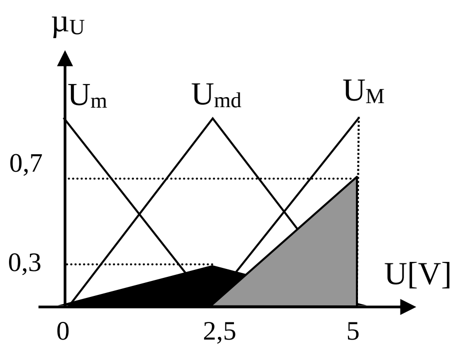

Fig.4

2.3. Defuzzyfication

In this case (for the studied application) we chose the most used defuzzyfication method which offers the most substantial results, the method of the gravity center (centroid). According to this method, if the fuzzy multitudes are determined through the method of inference with correlation through product, then it can be calculated the global gravity center, basis of the local gravity centers of each rule from BRF[2] . In this case: u_k=3,88.

3. Experimental results

The fuzzy regulator was software implemented, the communication between computer and the enclosure being made like in Fig. 1. The response of the system commanded with a fuzzy regulator, when at the input system is applied a step signal, is presented in Fig 5.

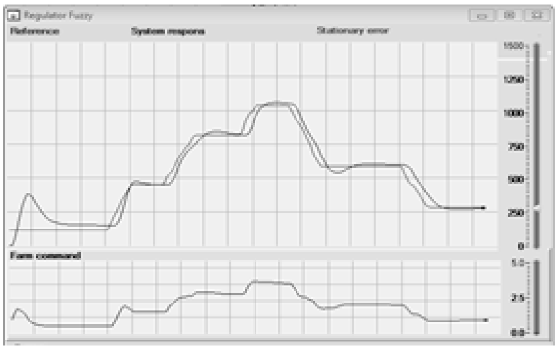

Fig. 5.

4. Conclusions

Adjustment system designed include the following benefits:

- as can be seen on the graph in Fig. 5, transient response duration and stationary error are very small fitting into acceptable limits;
- the system offers the possibility to easily change the controller parameters and reference pressure;
- the designed algorithm, does not require the determination of the mathematical model of the unmovable part.

References

[1] Preitl, Şt., Precup, E. *Introducere în conducerea fuzzy a proceselor*, Editura Tehnică, Bucureşti, 1995;

[2] Sofron, E., Bizon, N., Ioniţă, S., Radian, R., *Sisteme de control fuzzy. Modelare şi proiectare asistată de calculator*, Editura Tehnică, Bucureşti, 1998.