FUZZY LOGIC CONTROL

Zoltan **ERDEI**, Paul **BORLAN**
North University of Baia Mare, Eaton Electroproduction Romania
zoltan.erdei@cunbm.utcluj.ro, borlan.paul@gmail.com.

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Abstract*: In this paper the authors present the usefulness of fuzzy logic in controlling engineering processes or applications. Although fuzzy logic does not represent a novelty for the scientific and engineering field, it enjoys a great appreciation from those involved in the two domains. The fact that fuzzy logic uses sentences kindred with the natural language make it easier to comprehend that a complex mathematical model required by the classic control theory. In MatLab software there are dedicated toolboxes to this subject that make the design of a fuzzy controller a facile one. In the paper design methods of a fuzzy controller are being presented both in Simulink and MatLab.*

1. INTRODUCTION

Every day we can observe how our daily activity becomes more dependent of computers and electronic devices in order to control resources and processes from the real world.

Such an example can be seen on airports all around the world, where a plane pilot receives indications in order to land or take off safely, without the flight controller having to look on the window.

Soft computational approaches in decision making have grown in popularity in many fields. This is easily observed by the large number of technical papers that are published in journals and magazines as a result of conferences in all domains of engineering, production, science, medicine and business. Soft computational method is a fast evolving field and it implies knowledge, technics and methods from various sources.

We have chosen this subject for our paper because soft computational methods have a large applicability in the field of engineering and control, and also due to the fact that they are highly appreciated by engineers. Also there is dedicated software that gives a special attention to these technics, such as tools and toolboxes. For example in MatLab for fuzzy logic we have Fuzzy Logic Toolbox and for neural networks we have Neural Network Toolbox.

2. FUZZY CONTROL

Fuzzy logic controllers satisfy the same functions as conventional controllers, but they handle more complex control problems by heuristic models and mathematics given by the fuzzy logic, rather than mathematical models given by differential equations.

An approach for fuzzy control is a functional form of the fuzzy system, developed by Takagi and Sugeno, where there is no need for defuzzification. This model based fuzzy control method can be used when it is possible to describe the system's dynamics at a local level in adequate terms.

The main rule of the method is

$$R_j : If\ x_1\ is\ A_{j1}\ and\ \dots and\ x_n\ is\ A_{jn}\ then\ u_j = f_j(x_1, x_2, \dots, x_n) \tag{1}$$

for $j = 1,2, \dots, r$, where x_i represents the observed values of the input variables, f_j are functions and A_{ij} forms a fuzzy partition of the input system. Considering the product of A_{ij} we can express the rules in a more simple form

$$R_j : „If\ \boldsymbol{x}\ is\ A_j\ then\ u_j = f_j(x_1, x_2, \dots, x_n)” \tag{2}$$

The total output value is

$$u(x) = \sum_{j=1}^{r} A_j(x) f_j(x) \Big/ \sum_{j=1}^{r} A_j(x) \tag{3}$$

In the case of Takagi – Sugeno method each function f_j is liniar.

$$f_j(x_1, x_2, \dots, x_n) = a_{0j} + \sum_{i=1}^{n} \alpha_{ij} x_i \tag{4}$$

Other used forms are the quadratic

$$f_j(x_1, x_2, \dots, x_n) = a_{0j} + \sum_{i=1}^{n} a_{ij} x_i^2 \tag{5}$$

And the trigonometric

$$f_j(x_1, x_2, \dots, x_n) = \exp\left(\sum_{ij}^{n} \alpha_{ij} \sin x_i\right) \tag{6}$$

When choosing $f_j(\boldsymbol{x})$ we must take into consideration the particularities of the application.

3. TAKAGI – SUGENO FUZZY CONTROLLER

In this example we will design a fuzzy controller that respects the requirements of the Takagi – Sugeno controller. The design has been made in MatLab Simulink.

This controller has 2 inputs and an exit. First input is given by the error, *error=x*, and the second is given by the time differential of the error, *error_dot=y*. The output of the controller is the change in the control action and not the control itself.

The fuzzy membership functions for the primary and secondary inputs are isosceles triangular, 5 membership functions for each input. The membership function for the first entry has its peaks at $[-\mathrm{x_a}\ -x_a/2\ \ 0\ \ x_a/2\ x_a]$. The base of each triangle has a length of x_a. The triangular function for the second entry has its peaks at $[-y_a\ -y_a/2\ \ 0\ \ y_a/2\ y_a]$. The base of each triangle has a length of y_a. x_a and y_a have been set at 1. The output membership functions are NB (negative big), NM (negative medium), Z (zero), PM (positive medium) and PB (positive big).

The fuzzy rules are:

$$\begin{aligned}&R_{ij}, i = 1, \dots, 5; j = 1, \dots, 5\\&R_{11}: Dacă\ x\ este\ NB\ și\ y\ este\ NB\ atunci\ z\ este\ NB\\&R_{12}: Dacă\ x\ este\ NB\ și\ y\ este\ NM\ atunci\ z\ este\ NB\\&\vdots\end{aligned} \tag{7}$$

Output z is calculated according to

$$z = \sum w_{ij} z_{ij} / \sum w_{ij}, i = 1, \dots, 5; j = 1, \dots, 5 \tag{8}$$

w_{ij} represents the weigh of the rule ij (minimum between the membership degree of input 1 and the membership degree of input 2). z_{ij} is the value of z in rule ij.

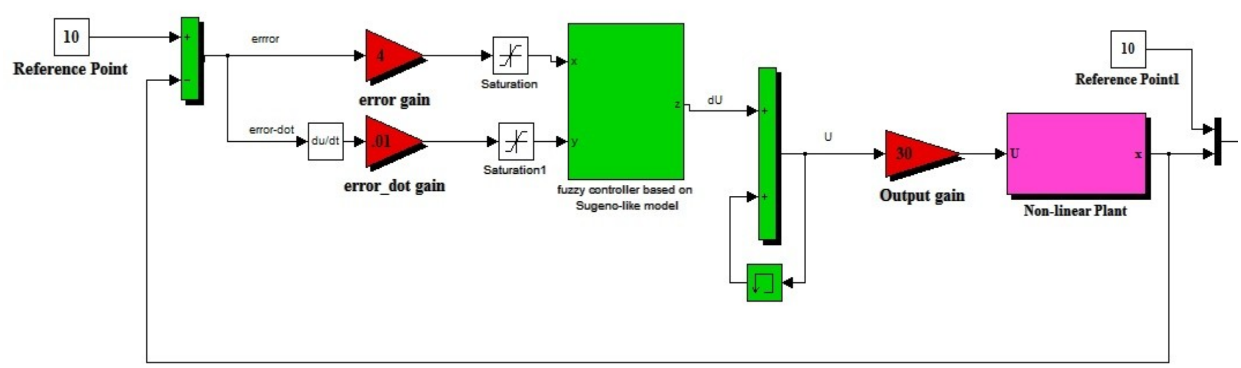

Fig 1. Block diagram of the Takagi – Sugeno controller

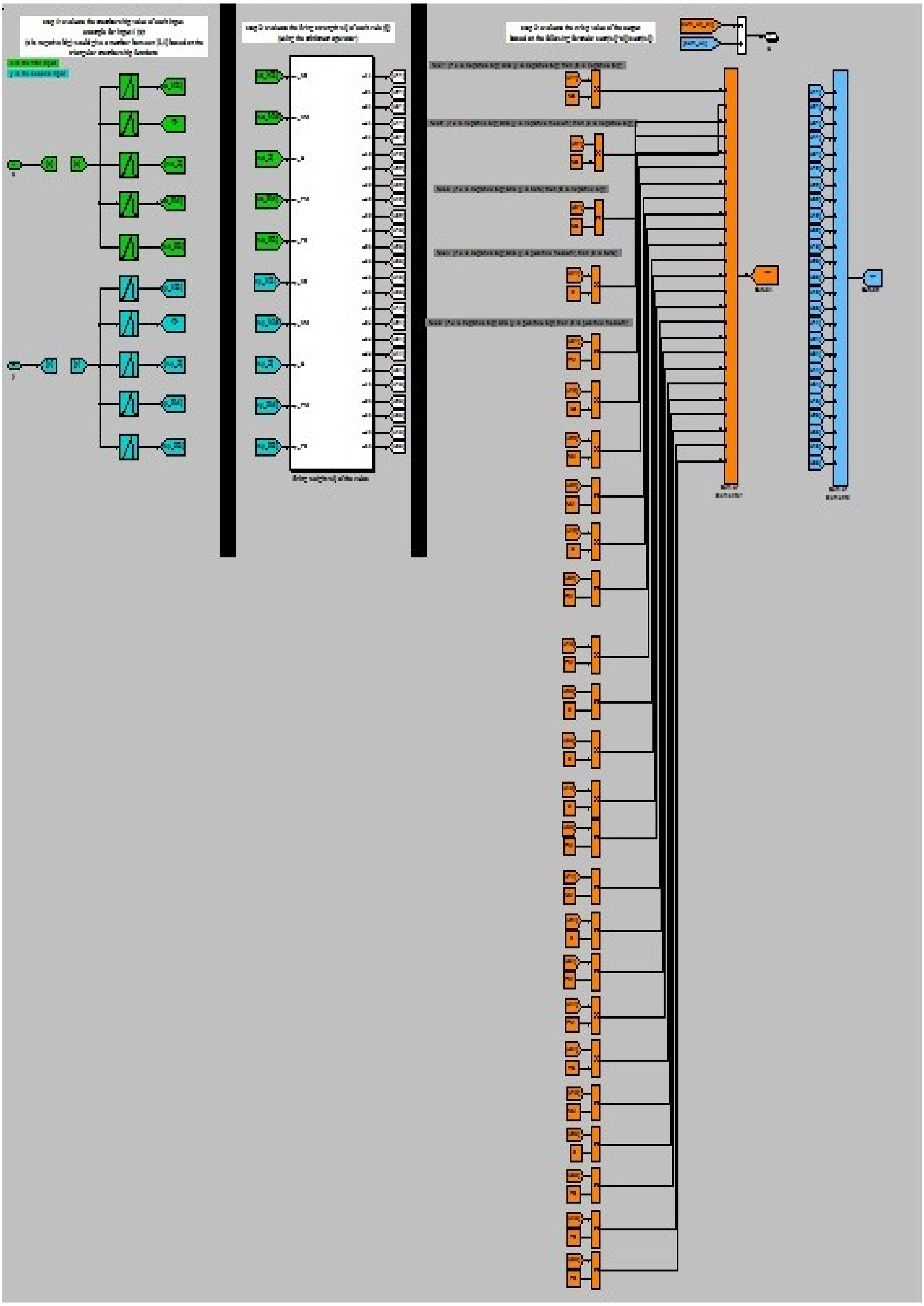

Fig. 2. The model of the controller

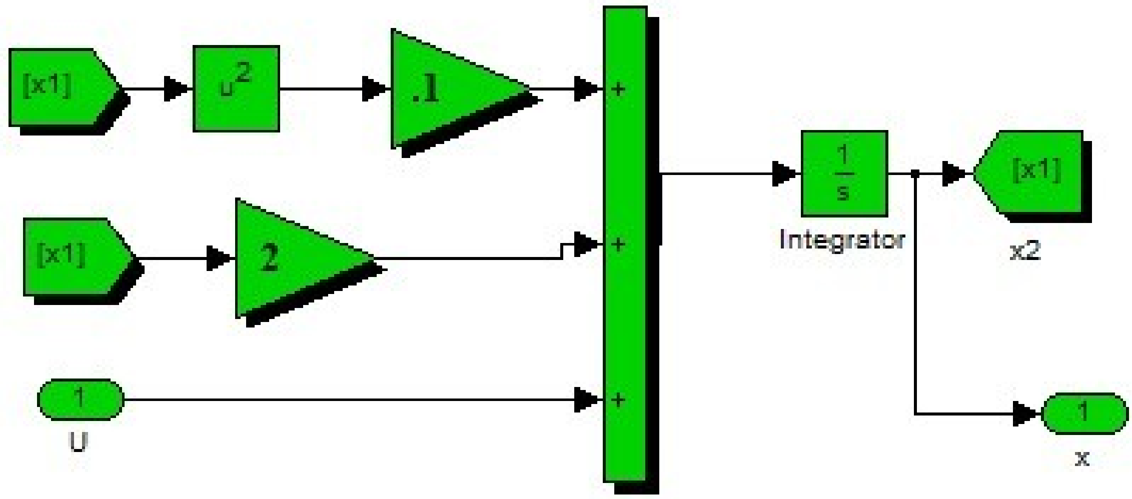

Fig. 3. The model of the system

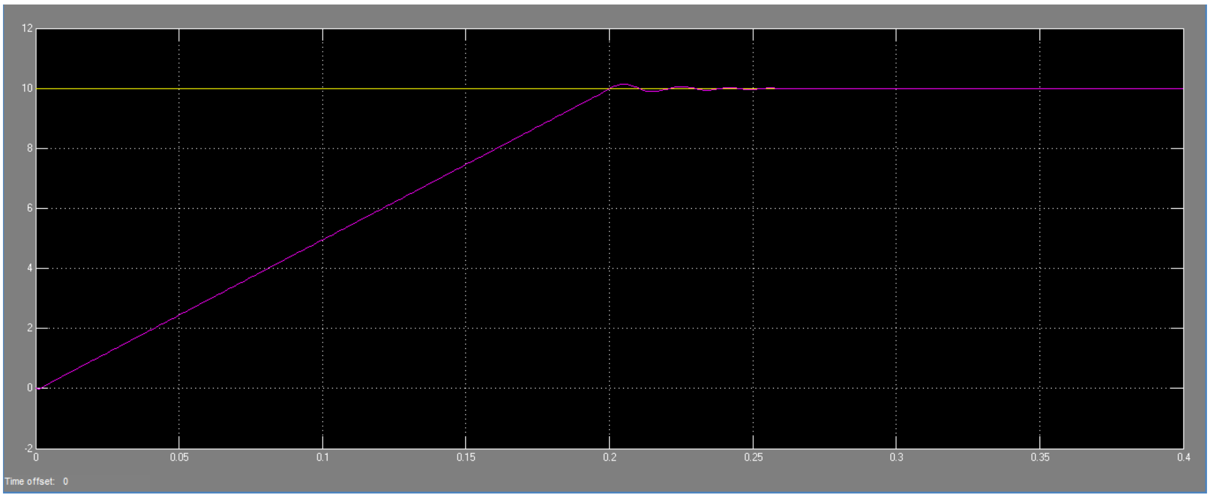

Fig. 4. The output of the controller

4. CONCLUSIONS

As it can be observed in the upper graph rises linearly to the desired value, and once this value is achieved there are fluctuations from the target, and through fuzzy control this value is manipulated and in this way we can obtain what we want from the system.

REFERENCES

1. **S. Abe and M.S. Lan**, *A method for fuzzy rule extraction directly from numerical data and its application to pattern recognition*, IEEE Trans. On Fuzzy Systems, 3, 18-28, 1995.
2. **G. Bojadziev and M. Bojadziev**, *Fuzzy Sets, Fuzzy Logic*, Applications, World ScientiÞc, London, 1995.

3. **E. Czogała and J. Łeþski**, *Fuzzy and Neuro-Fuzzy Intelligent Systems*, Springer-Verlag, Berlin, 2000.
4. **C.W. de Silva**, *Intelligent Control: Fuzzy Logic Applications*, CRC Press, Boca Raton, FL, 1995.
5. **R.C. Dorf**, ed., *The Electrical Engineering Handbook*, CRC Press, Boca Raton, FL, 1993.
6. **K. Dutton, S. Thompson, and B. Barraclough**, *The Art of Control Engineering*, Addison-Wesley Longman, Ltd., Essex, UK, 1997.
7. **M. Gehrke, C.L. Walker, and E.A. Walker**, *Normal forms and truth tables for fuzzy logics*, chapter in Proceedings of Linz 2000 Conference, Fuzzy Sets and Systems,2000.
8. **G.C. Goodwin, S.F. Graebe, and M.E. Salgado**, *Control System Design*, Prentice-Hall, Upper Saddle River, NJ, 2001.
9. **F. Höppner, F. Klawonn, and R. Kruse**, *Fuzzy Cluster Analysis*, JohnWiley & Sons, New York, 1999.
10. **J.S.R. Jang**, *ANFIS: adaptive-network-based fuzzy inference system*, IEEE Transactions on Systems, Man and Cybernetics, 23(3), 665-684, 1993.
11. **S.V. Kartalpoulos**, *Understanding Neural Networks and Fuzzy Logic*, IEEE Press, Piscataway, NJ, 1996.
12. **R.J. Marks** II, ed., *Fuzzy Logic Technology, and Applications*, IEEE Technology Update Series, IEEE Press, Piscataway, NJ, 1994.
13. **H.T. Nguyen, M. Sugeno, and R. Yager**, eds., *Theoretical Aspects of Fuzzy Control*, John Wiley & Sons, New York, 1995.
14. **H.T. Nguyen and E.A.Walker**, *A First Course in Fuzzy Logic,* 2nd Edition, CRC Press, Boca Raton, FL, 1999.
15. **K.M. Passino and S. Yurkovich**, *Fuzzy Control*, Addison-Wesley Longman, Menlo Park, CA, 1998.
16. **W. Pedrycz**, *Fuzzy Sets Engineering*, CRC Press, Boca Raton, FL, 1995.
17. **C.L. Phillips and R.D. Harbor**, *Feedback Control Systems*, 4th Edition, Prentice-Hall, Upper Saddle River, NJ, 2000.
18. **T.J. Ross**, *Fuzzy Logic with Engineering Applications*, McGraw-Hill, New York, 1995.
19. **M. Sugeno**, *Fuzzy Measure and Fuzzy Integral*, Trans. SICE, 8(2), 95-102, 1972.
20. **T. Takagi and M. Sugeno**, *Fuzzy identifcation of systems and its applications to modeling and control*, IEEE Trans. Systems, Man and Cybernetics, 15(1), 116-132, 1985.
21. **K. Tanaka and M. Sugeno**, *Stability analysis and design of fuzzy control systems*, Fuzzy Sets and Systems, 45, 135-150, 1992.
22. **K. Uehara and M. Fujise**, *Fuzzy inference based on families of alpha-level sets*, IEEE-Transactions on Fuzzy Systems, 1(2), 111-24, May 1993.
23. **L.X. Wang**, *Fuzzy systems are universal approximators*, Proceedings of the First IEEE Conference on Fuzzy Systems, San Diego, CA, 1163-1170, March 1992.
24. **B. Werners**, *An interactive fuzzy programming system*, *Fuzzy Sets and Systems*, 23, 131-147, 1987.
25. **R.R. Yager**, *On a general class of fuzzy connectives, Fuzzy Sets and Systems*, 4, 235-242, 1980.
26. **H.J. Zimmermann**, *Fuzzy Set Theory and its Applications*, 2nd Edition, Kluwer Academic Publishers, Dordrecht, The Netherlands, 1991.
27. **H.T. Nguyen**, *N.R. Prasad, C.L. Walker, E.A. Walker, A first course in Fuzzy and Neural Control*, Chapman & Hall/CRC, 2003
28. **Y. Dote**, *Introduction to Fuzzy Logic, Industrial Electronics, Control, and Instrumentation*, Orlando, 50-56, November 1995