Quick Comparison of the Efficiency of Fuzzy Operatios Used in FLC

Márta Takács, Ágnes Szeghegyi

Budapest Tech
Bécsi út 96/B, H-1034 Budapest, Hungary
takacs.marta@nik.bmf.hu, szeghegyi.agnes@kgk.bmf.hu

Cludiu Pozna

Universitatea Transilvania Brasov, Romania
cp@unitbv.ro

Abstract: The practical realization of the Fuzzy Logic Controler (FLC) usually depends on the application. Using the parameter-depended group of fuzzy operators like distance based operators in the approximate reasoning process the FLC components can be adapted to achieve better results. The program language environment, applied by simulation, supports the choosing of suitable fuzzy operators and their parameters. The simulation results are analysed, depending on the efficiency of the operator choice in approximate reasoning model.

Keywords: approximate reasoning, fuzzy control

1   Introduction

The underlying notions of soft-computing systems are flexibility and the human mind. The choice of the fuzzy environment must support the efficiency of the system, it must comply to the real world. This is more important than trying to fit the real world into the inflexible models. [1],[2]

In the paper it is presented how distance based operators in FLC approximate reasoning can be applied. Considering that the distance based operators are parameter-dependent norms, we influence the behavior of the system by changing or sliding the parameter values. Along with the operators in the approximate reasoning model, the structure of the fuzzy sets can also be modified in order to improve the behavior of the experimental system. It outlines the foundations of a future adaptive system, which is based on earlier research results.

After the problem definition and descripiton of some possible ways of solution, the experimental results are explained. The simulation model is a satellite controler model. The fuzzy controler was built in a MATLAB environment, first based on fuzzy toolbox, and then using a new program interface, where some elements from a given fuzzy toolbox are extended with the possibilities of the operator choise in the fuzzy approximate reasoning.

2   Main Steps in the Building of the Simulation System

To explain the behavior of a controlled system using distance based operators in the fuzzy reasoning case, we design a MATLAB program, which allows a quick comparison of the effiency of used operators in FLC. More precisely the used operators group depends on e parameter $(e \in [0,1])$, and tuning the controller means to choose the value of e. Simulation of control for the parameter e can be a tuning solution. To do this it is necessary to compare different results, for different values of e (and even for different operators).

The proposed solution combines three toolboxes of Matlab:

I   Fuzzy Logic Toolbox: where the user will be able to design the fuzzy controller. There are several ways to do that. We recommend to use the *fuzzy* GUI (General User Interface) where interactively the user can establish:

  –   the number of inputs and outputs;

  –   the membership functions;

  –   the rules;

  –   the And, Or methods (generalized t-norms and t-conorms applied in the fuzzy approximate reasoning process);

  –   the implication, aggregation and defuzzyfication methods;

II   Simulink: where the user will be able to design the Control Diagram. Mainly this diagram is composed from:

  –   the plant model;

  –   the actuator model;

  –   the sensor model;

  –   the controller model which is an object from Simulink –> Fuzzy Logic Toolbox –>Fuzzy Logic Controller with Ruleviewer. In fact this object imports the fuzzy logic controller (designed with fuzzy logic toolbox) in a Simulink diagram;

III Matlab GUI, where we have designed a program (Smarta) which allows the following actions:

- – open the Simulink file where the user has designed the control diagram;

- – open the Fuzzy Logic (FL) controller;

- – change the values of e parameters from the And, Or methods;

- – start the simulation;

- – store the simulation results;

- – because there are many simulation results stored the program can plot different combinations of this results, so in this way a comparison will be possible.

In addition to this structure the user must create two MATLAB files which consist of And, Or methods (used t-norms and conorms). The diagram from Figure 1 illustrates this structure.
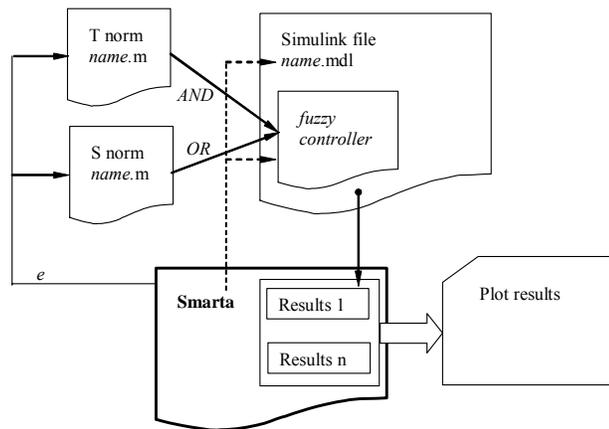

Figure 1
The solution structure

3   Simulation Results

The behavior of a system to be controlled by different FLC models is investigated in an example of satellite control. In Figure 2 illustrates the satellite whose angular (spin) position we intend to control. The satellite has two jet actuators. Because of the actuator behavior the control problem is nonlinear.

The dynamical model of the plant (satellite) is

$$\ddot{\theta} = u \tag{1}$$

where: (from simplicity reasons J=1), θ is the spin angle, u torque generated by the jet actuators. Because the torque value is $\pm u$ where u is a constant value we can choose to control the plant with the diagram from Figure 3.
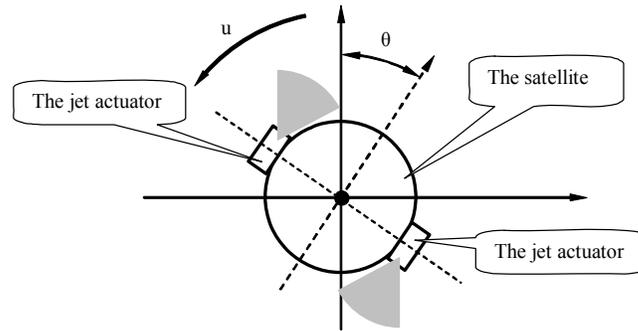

Figure 2

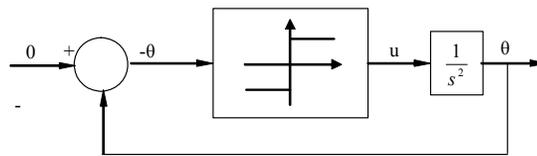We intend to control the angular position of the satellite

Figure 3

Control diagram (first idea)

The dynamical behavior of the plant will be:

$$\ddot{\theta} = sign(-\theta)u \Rightarrow \frac{d\dot{\theta}}{d\theta} \cdot \frac{d\theta}{dt} = sign(-\theta)u \Rightarrow \dot{\theta}d\dot{\theta} = sign(-\theta)u \cdot d\theta \Rightarrow$$

$$\int \dot{\theta}d\dot{\theta} = \int sign(-\theta)u \cdot d\theta \Rightarrow \dot{\theta}^2 = 2sign(-\theta)\theta u + c \tag{2}$$

Using special trajectories and the dynamical behavior of the plant the satellite will have an un-damped oscillation (see Figure 4).
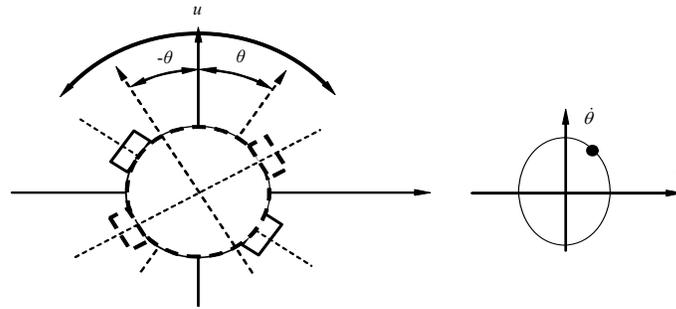
Figure 4

The satellite behavior

3.1 Classic Fuzzy Control Solution

We will denote this solution *Classic Fuzzy* because in the construction of the FLC we use the classical min, max rules. In order to simulate the fuzzy controller we have constructed the Simulink diagram from Figure 5. The object *Fuzzy Logic Controller with Rule viewer* links the FL application to this diagram. This application was designed in Fuzzy Logic Toolbox.
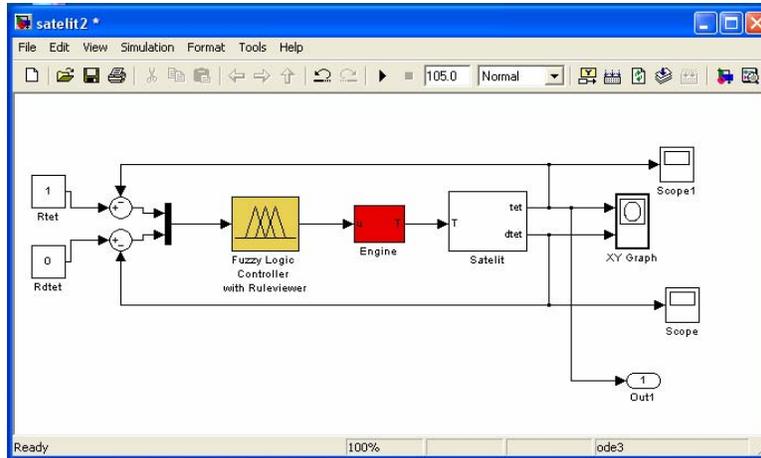

Figure 5

The Classical Fuzzy solution

In order to obtain the desired behavior we changed the range of the angular speed *Universe*. When we refined this range (consider a smaller Universe) the importance of angular speed has increased. The results are presented in Figure 6.
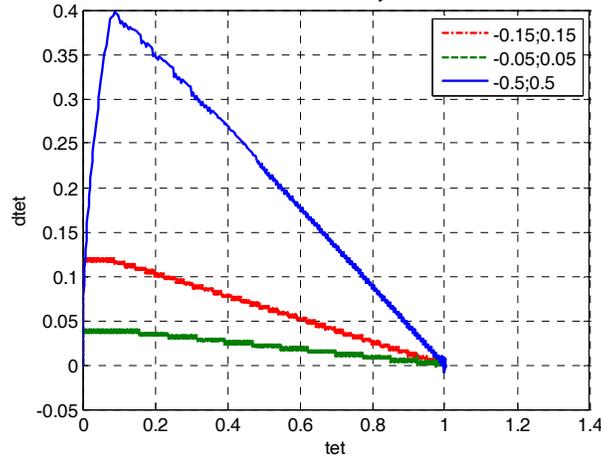
Figure 6

Results, comparison for several values of the angular speed range(tet=θ; dtet= $\dot{\theta}$)

3.2 Using the Program-Interface Tool and Test of Several Pairs of The T-norms and Conorms

The modified FLC model, presented in [3] is the base of the investigation in this case. The if .. then … rules from the rule base and the influence of the sysytem input on the rules is modeled by minimum distance maximum operator, which is a conjunctive fuzzy operator (AND operator). The aggregation of all rule-outputs is done with the minimum distance minimum operator, which is a disjunctive type operator (OR operator). Both of the operators are dependent on the parameter *e*.

Th*e minimum distance maximum operator with respect* to $e \in [0,1]$ is defined as

$$\min{}_e^{\max} = \begin{cases} \min(x, y), & \text{if } y > 2e - x \\ \max(x, y), & \text{if } y < 2e - x \, . \\ \max(x, y), & \text{if } y = 2e\text{-}x \end{cases} \tag{3}$$

The *maximum distance maximum operator with respect to* $e \in [0,1]$ is defined as

$$\max{}_e^{\max} = \begin{cases} \max(x, y), & \text{if } y > 2e - x \\ \min(x, y), & \text{if } y < 2e - x \, . \\ \max(x, y), & \text{if } y = 2e\text{-}x \end{cases} \tag{4}$$

The structure of the program was presented in Figure 1. After we had realized the program for the description of T and S norms, which are respectively (3) and (4), we have used the Smarta and we have obtained the results as described below.

Comparison of the Controller Behavior for Several Values of *e* Parameter

We can conclude, that changing the parameter value, there is a measurable difference between results (the relative difference between results may be 30%). It proves again that building simulation systems before the realisation of the system working, it is possible to test possibilities, and choose the best solution and the suitable fuzzy operators in FLC. It can be seen that increasing the value of *e* parameter is similar to increasing Kd parameter of PID controller: decreasing the dominant poles value and transform them from real to complex (with non zero imaginary parts, see Figure 7).
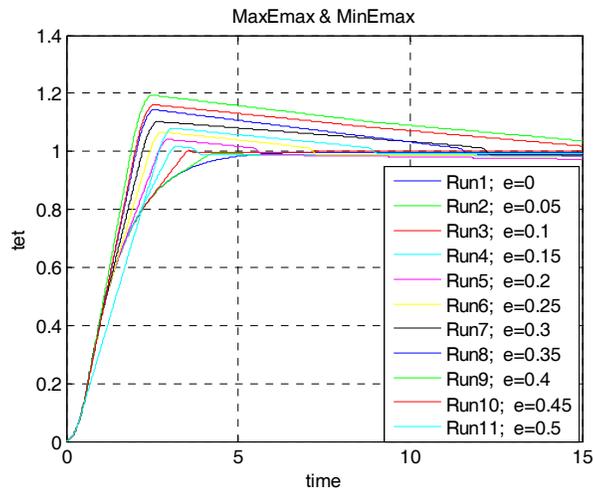

Figure 7

Comparison for several values of *e* for the step form of tet=*θ*

For this result, in Figure 8, a state space representation is plotted, like in Figure 6.

Conclusions

A quick way to investigate the parameter-based operator group applying in FLC was constructed and tested on a satellite control problem. In order to use a quick program the following steps are needed:

−   Construct your And and Or operators by two Matlab files;

−   Construct your fuzzy logic control application using Fuzzy Logic Toolbox, and connect to this application the two And and Or operators;

−   Construct your Control Diagram in Simulink, (Plant, Sensor, ... Controller). The controller is an object from Fuzzy Logic Toolbox (from Simulink library) which link your FL application to the Simulink application;
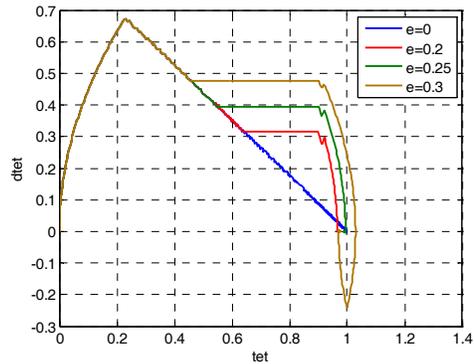
Figure 8

The state space representation (tet=θ; dtet=$\dot{\theta}$), using *min e max* and *max e max* operators pair

− Save all this file in the same directory, close the applications;

− These steps can be done for several methods, FL controllers, and Control Diagrams opening and runing the quick program.

It is a measurable difference between outputs using the scale of different *e* parameter-based distance based operators.

Acknowledgement

References

[1] L. A., Zadeh: *A Theory of Approximate Reasoning*, In Hayes, J., and editors, Mashine Intelligence, Vol. 9, Halstead Press, New York, 1979, pp. 149-194

[2] L. Horváth, I. J. Rudas: *Human Intent Description in Environment Adaptive Product Model Objects*, Journal of Advanced Computational Intelligene and Intelligent Informatics, Tokyo, Vol. 9, No. 4, pp. 415-422, 2005

[3] M. Takács: *Decision-Making with Distance-based Operators in in Fuzzy Logic Control*, in Proceedings of the 3rd International Symposium of Hungarian Researchers on Computational Intelligence, Budapest, Nov. 2002, pp. 111-118