

Advantages of Fuzzy Control Application in Fast and Sensitive Technological Processes

Radim Farana, Bogdan Walek, Michal Janosek, Jaroslav Zacek

Abstract—This paper presents the advantages of fuzzy control use in technological processes control. The paper presents a real application of the Linguistic Fuzzy-Logic Control, developed at the University of Ostrava for the control of physical models in the Intelligent Systems Laboratory. The paper presents an example of a sensitive non-linear model, such as a magnetic levitation model and obtained results which show how modern information technologies can help to solve actual technical problems. A special method based on the LFLC controller with partial components is presented in this paper followed by the method of automatic context change, which is very helpful to achieve more accurate control results. The main advantage of the used system is its robustness in changing conditions demonstrated by comparing with conventional PID controller. This technology and real models are also used as a background for problem-oriented teaching, realized at the department for master students and their collaborative as well as individual final projects.

Keywords—Control, fuzzy logic, sensitive system, technological proves.

I. INTRODUCTION

FUZZY logic has been invented by Prof. Zadeh [1] and used to describe uncertain systems [2] since the 60's of the 20th century. This technique has also been used in control systems. Fuzzy control is now the standard control method which is a constituent of many industrial systems and companies advertise it no more. The used technique is mostly based on application of fuzzy IF-THEN rules; either of the form first used by Mamdani [3], or by Takagi and Sugeno [4].

The success of fuzzy logic control is based on the fact that a description of real systems is quite often imprecise. The imprecision arises from several factors—too large complexity of the controlled system, insufficient precise information, presence of human factor, necessity to spare time or money, etc. Frequently, combination of more such factors is present.

A special system for fuzzy logic control has been developed at the University of Ostrava by Prof. Novák and his team [5]-[7], based on linguistic description. The Linguistic Fuzzy Logic Controller (LFLC) is the result of application of the formal theory of the fuzzy logic in broader sense (FLb). The fundamental concepts of FLb are evaluative linguistic expressions and linguistic description. Evaluative (linguistic) expressions are natural language expressions such as small, medium, big, about twenty-five, roughly one hundred, very short, more or less deep, not very tall, roughly warm or

medium hot, roughly strong, roughly medium important, and many others. They form a small, but very important, constituent of natural language since we use them in common sense speech to be able to evaluate phenomena around. Evaluative expressions have an important role in our life because they help us determine our decisions; help us in learning and understanding, and in many other activities.

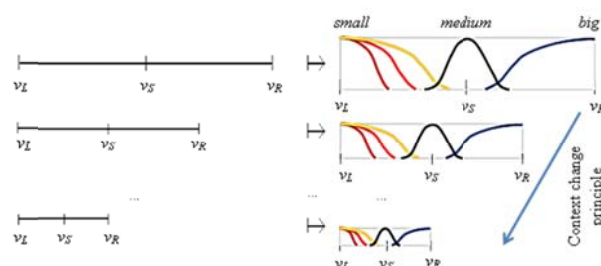


Fig. 1 A general scheme of intension of evaluative expressions (extremely small, very small, small, medium, big) as a function assigning a specific fuzzy set to each context [7]

Simple evaluative linguistic expressions (possibly with signs) have a general form <linguistic modifier><TE-adjective> (where <TE-adjective> is one of the adjectives (also called gradable) “small – sm, medium – me, big – bi” or “zero – ze”. The <linguistic modifier> is an intensifying adverb such as “extremely – ex, significantly – si, very – ve, rather – ra, more or less – ml, roughly – ro, quite roughly – qr, very roughly – vr”) (Fig. 1). LFLC is a good tool to define the control strategy. It is also used for control of technological processes with sampling period 0.01 [s] or less. The paper presents an example of sensitive non-linear model such as a helicopter model, representing a very fast control system. This model is very helpful for application, because its description and mathematical model is available, for example [8]. Previous paper [9] presented LFLC control application for two laboratory models – helicopter model and magnetic levitation model with very good results, better than standard PID control. Therefore, this paper deals with the further development LFLC control application.

II. MAGNETIC LEVITATION CONTROL

The magnetic levitation model (Fig. 2) represents a nonlinear, sensitive, one-dimensional system. We are unable to use classical identification methods to obtain the mathematical model. Fortunately, we have a very good mathematical model developed by the model producer [8]. The control system was derived from the standard producer

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design in Matlab/Simulink environment, we also have the PID controller set up to control the magnetic levitation object position, which could be used as a reference for our LFLC controller (Fig. 3).

PIC controller parameters were optimized for the middle position of the levitating object (0.5). Fig. 4 presents the control result with very good control quality.



Fig. 2 Magnetic levitation model

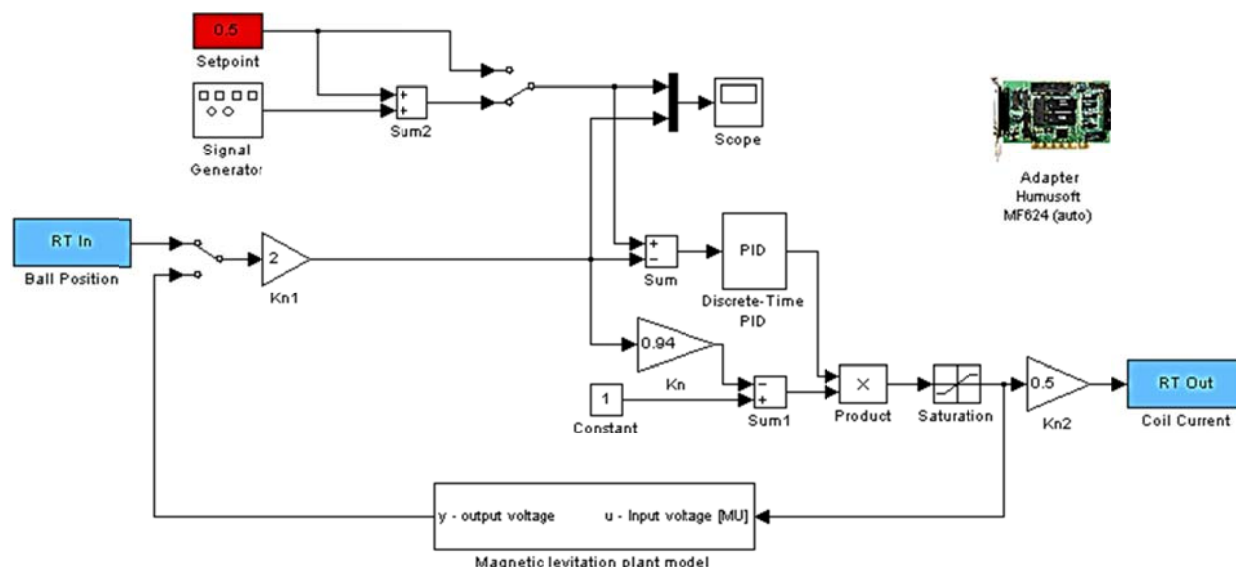


Fig. 3 PID control developed by the magnetic levitation model producer

Analyzing the PID control, we will see that the control error first derivative value is hundred times higher than the control error value and the second derivative value is hundred times higher than the first derivative value. This is caused by the sampling period $T = 0.002$ [s]. Thus, we cannot develop classical fuzzy controller based on three input values – control error and its first and second derivatives. For these cases, we develop a special strategy based on multiple use of LFLC controllers (Fig. 5).

Every partial LFLC controller will react to one input value. Outputs from all partial controllers will be summarized in a discrete integrator. It is also easy to change the control strategy, e.g. a very small reaction to a small error and a very big reaction to a big error to obtain the needed value faster (Fig. 6). Table I presents the LFLC controller contexts set up for partial controllers based on the controlled object behavior. The LFLC control result is shown in Fig. 7. We see that the control process is of lower quality. This is typical for fuzzy control because of some limitation of LFLC control, presented in previous paper [9]. Thus further possibilities to change the control system and to obtain the control error derivative, such as FIR filters, see [10] were tested.

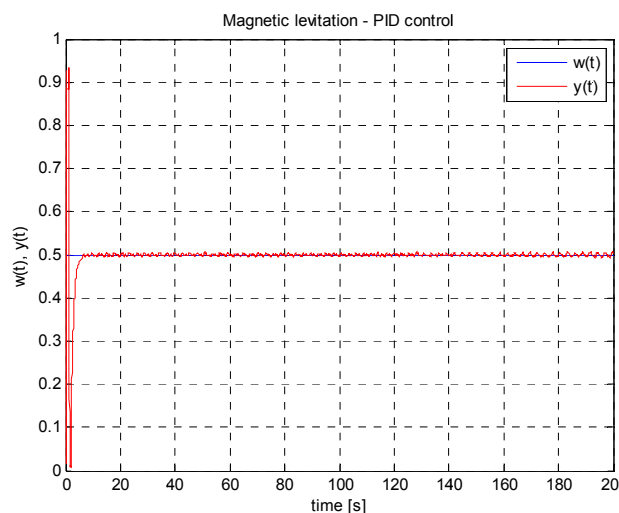


Fig. 4 PID control results

TABLE I
LFLC CONTROLLER CONTEXTS

Input Value	Scale	Transfer coefficient	Output scale
de	$-50 \div 50$	1	$-50 \div 50$
e	$-0,5 \div 0,5$	10	$-5 \div 5$
d^2e	$-40000 \div 40000$	0,03	$-1200 \div 1200$

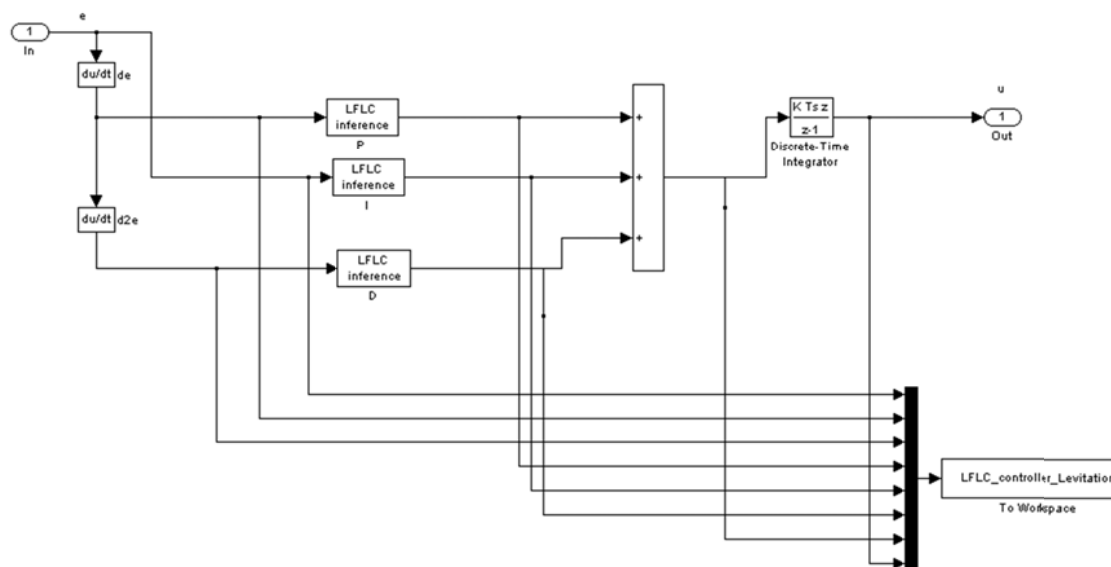


Fig. 5 LFLC controller developed for the magnetic levitation model

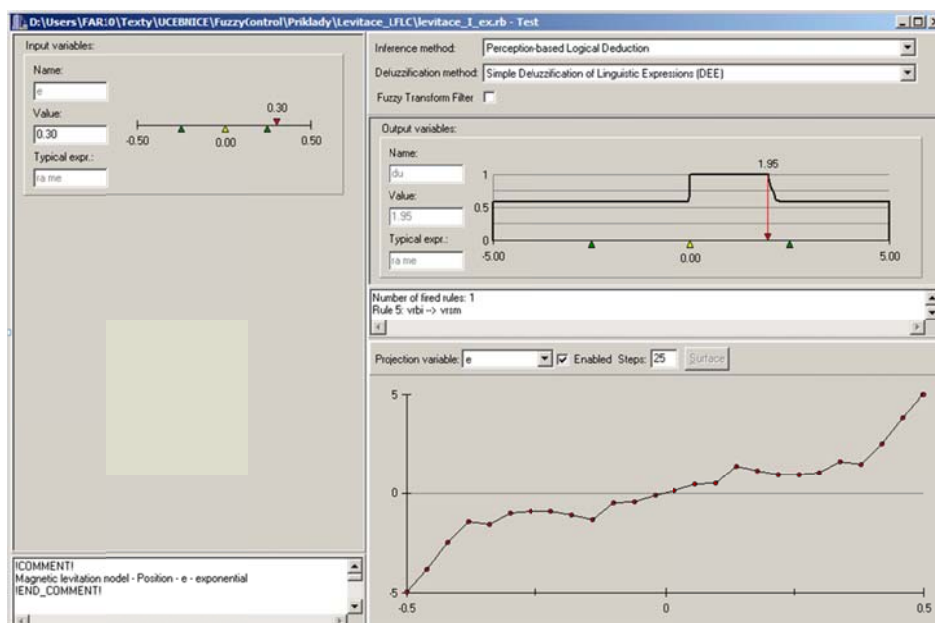


Fig. 6 LFLC controller behavior

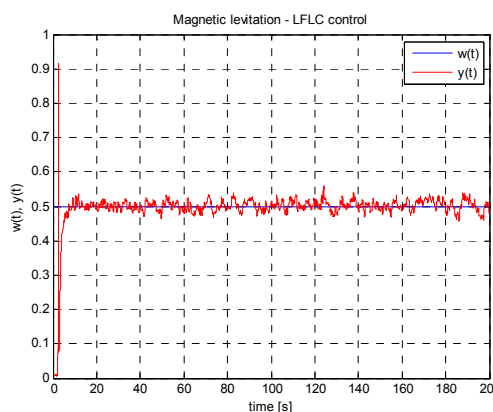


Fig. 7 LFLC control results

The primary problem is the tendency for sustained oscillations of the system when keeping a constant position is required, a limited accuracy to achieve it respectively. This is due a limited number of fuzzy values for small control error values. An idea how to improve the control system behavior was proposed and presented by Prof. Novák in his previous publications [7], [11]. It is based on an automatic LFLC controller context change. The main principle of automatic context change is shown in Fig. 1. To develop LFLC controller with automatic control change, we can use another LFLC controller (Figs. 8 and 9). This strategy can approve the control quality very well, as presented in previous paper [12].

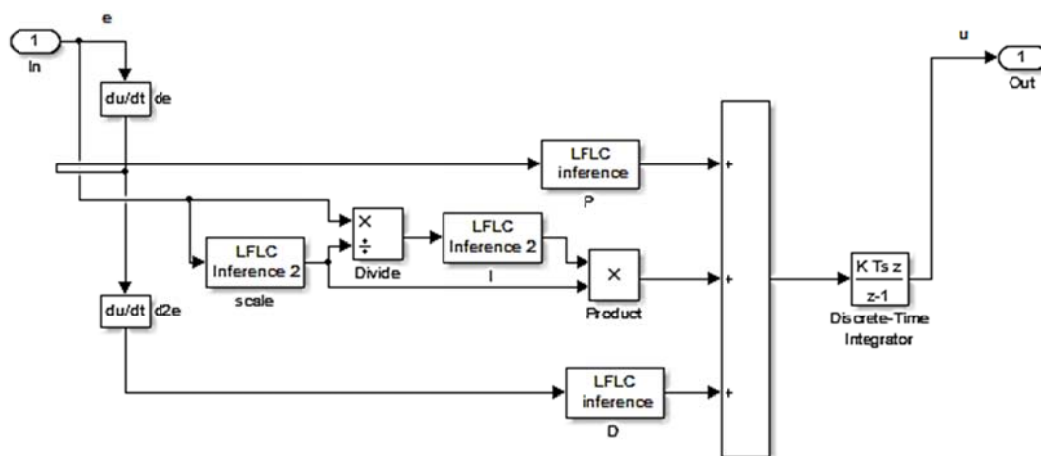


Fig. 8 LFLC controller with automatic context change

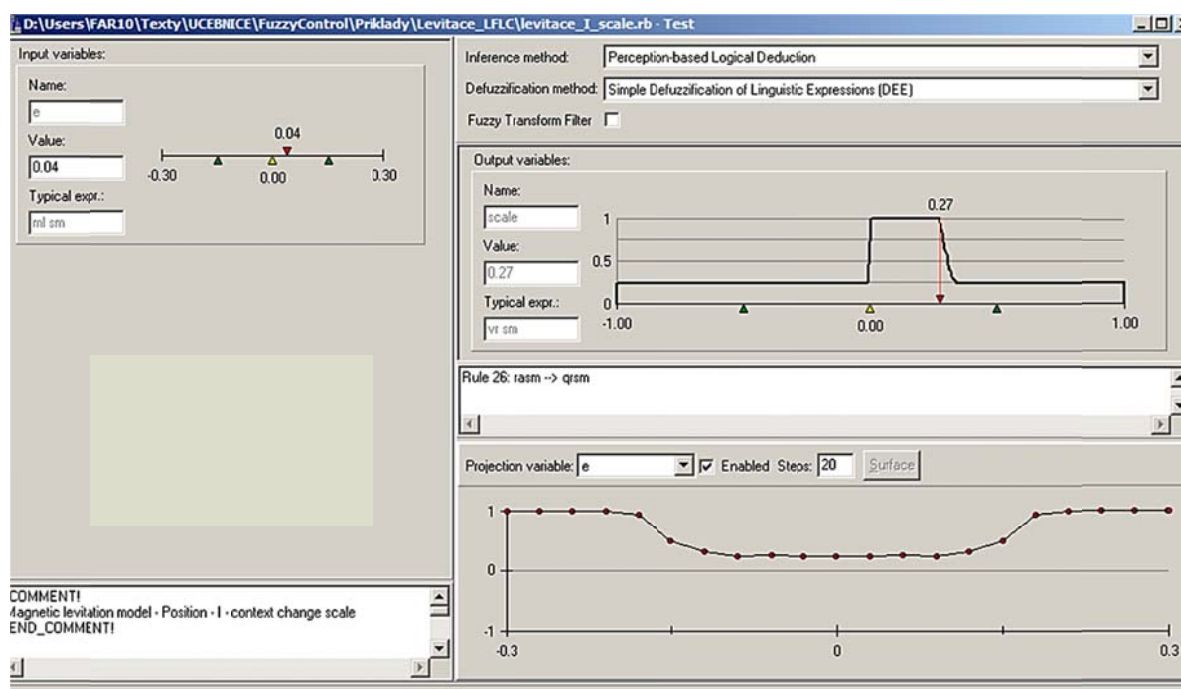


Fig. 9 Automatic context change realization

To present the advantages of fuzzy control, we use the desired value generated as a pulse signal changing position between 0.3 and 0.7. Fig. 10 presents the PID control results. We see that the magnetic levitation object is very sensitive and the control process is unstable. The control system has a great problem to stabilize the desired position closer to the electromagnet. The system behavior is too different in different levitation object positions because of system nonlinearities.

LFLC control used in the same situation gives us different results (Fig. 11). The position even closer to the electromagnet was stabilized thanks to the robustness of the fuzzy logic control. That is the main advantage of the fuzzy control application in technological systems control.

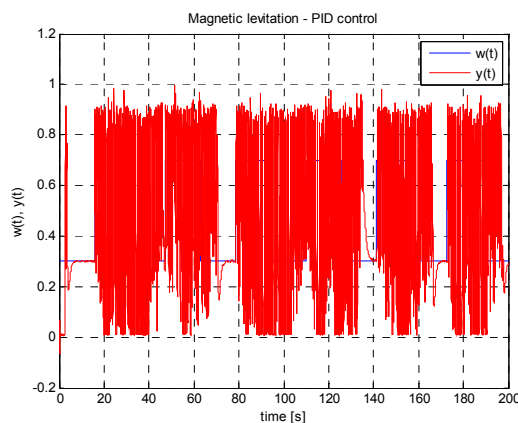


Fig. 10 PID control results for pulse signal

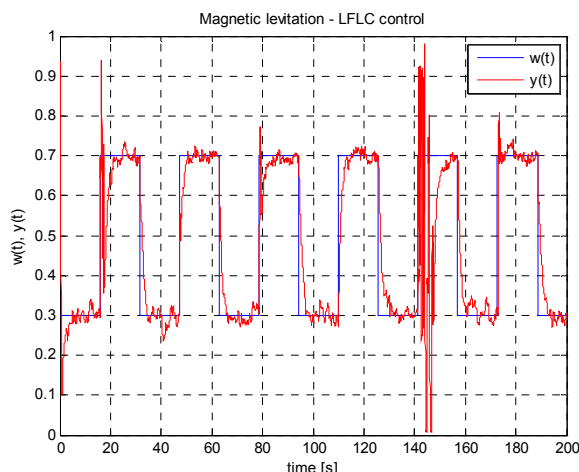


Fig. 11 LFLC control results for pulse signal

III. CONCLUSION

The presented examples of LFLC use have been solved at the University of Ostrava. Obtained results show that modern numerical methods, such as Fuzzy Logic Control, are usable for control of fast technological processes with sampling period 0.01 [s] or less. The Linguistic Fuzzy-Logic Control, developed at the University of Ostrava, is a very helpful tool for control strategy description. The presented results proved how the used technology can help people easily describe control strategy from the technological control strategy point of view. The automatic context change significantly increases the usability of the whole system. The main advantage of fuzzy control is the robustness when the system parameters are changing, as presented on the magnetic levitation model. This technology and real models are used as a background for problem-oriented teaching, realized at the Department of Informatics and Computers, Faculty of Science, for master students and their collaborative as well as individual final projects. Students learned how to define the control strategy and verify it on a real helicopter model. Having completed these projects, students are able to define control strategies based on LFLC for any similar controlled system. They also compare obtained results with different Fuzzy control strategies, for example [13]–[15].

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