Application of Linguistic Fuzzy-Logic Control in Technological Processes

Radim Farana

Abstract This paper presents the use of modern numerical methods such as Fuzzy Logic Control for control of fast technological processes with sampling period 0.01 [s] or less. The paper presents a real application of the Linguistic Fuzzy-Logic Control, developed at the University of Ostrava for the control of magnetic levitation model in the laboratory at the Institute for Research and Applications of Fuzzy Modeling and Department of Informatics and Computers, Faculty of Science. 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. The paper shows how the used technology can help people easily describe the control strategy from the technological control strategy point of view.

Keywords Fuzzy logic · Control · LFLC · Magnetic levitation

1 Introduction

Fuzzy logic has been invented by Prof. Zadeh [1] and used to describe uncertain systems [2] since the 60s 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 in 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

R. Farana (✉)
University of Ostrava, 30 dubna 22, 701 00 Ostrava 1, Czech Republic
e-mail: radim.farana@osu.cz

R. Silhavy et al. (eds.), *Modern Trends and Techniques in Computer Science*, Advances in Intelligent Systems and Computing 285, DOI: 10.1007/978-3-319-06740-7_8,

the controlled system, insufficient precise information, presence of human factor, necessity to save time or money, etc. Frequently, a combination of several of 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.

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"), see Fig. 1. LFLC is a good tool to define the control strategy, then we also use it to control technological processes with sampling period 0.01 [s] or less. This paper presents results obtained when solving problems with control of a magnetic levitation 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], see Fig. 2.

2 Magnetic Levitation

Magnetic levitation is a very complex nonlinear problem. We are unable to use classical identification methods to obtain a mathematical model. Fortunately, we have a very good mathematical model developed by the model producer [8], see Fig. 3.

We also have the PID controller set up to control the magnetic levitation object position, which could be used as a reference for our fuzzy controller, see Fig. 4.

A control result for a desired value generated as a pulse signal is shown in Fig. 5. We see that the magnetic levitation object is very sensitive and the control process is unstable. The control system stabilized the desired position closer to the electromagnet only once.

Analyzing the PID control, we can see that the first derivative value is hundred times higher than the control error value and the second derivative value is hundred times higher than first derivative value. This is caused by the sampling period

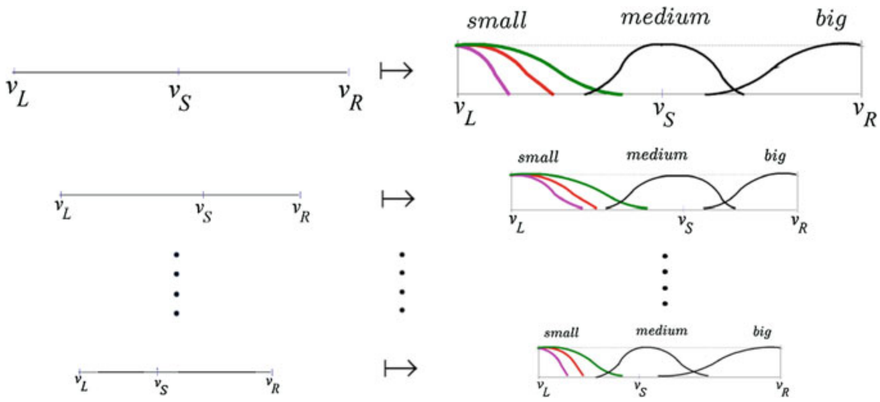

Fig. 1 A general scheme of intension of evaluative expressions (extremely small, very small, small, medium, big) as a function assigning a specific fuzzy set [7] to each context $w \in W$

Fig. 2 Magnetic levitation model

$T = 0.002$ [s]. Then we cannot develop a 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, see Fig. 6.

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, for example a very small reaction to a small error and a very big reaction to a big error to obtain the needed value faster, see Fig. 7.

Table 1 presents the LFLC controller contexts set up for a partial controller based on the controlled object behavior. The LFLC control result is shown in

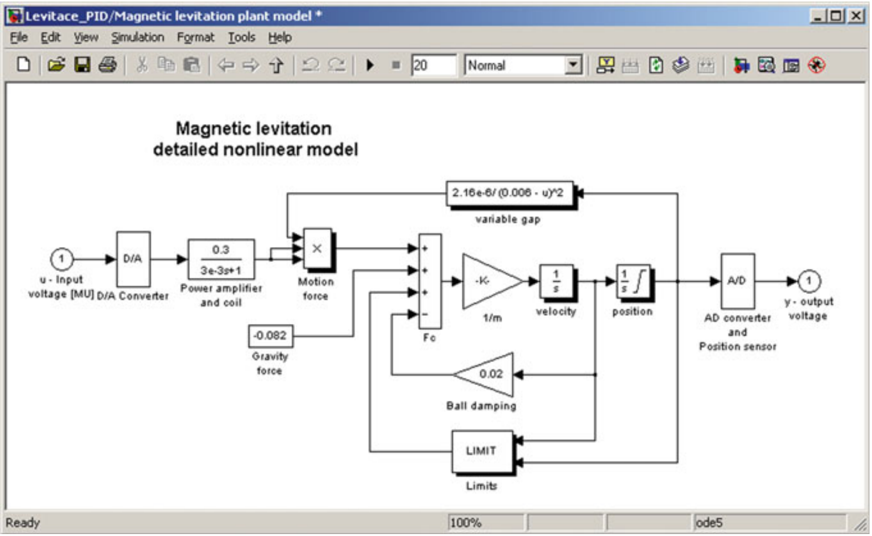

Fig. 3 Magnetic levitation simulation model

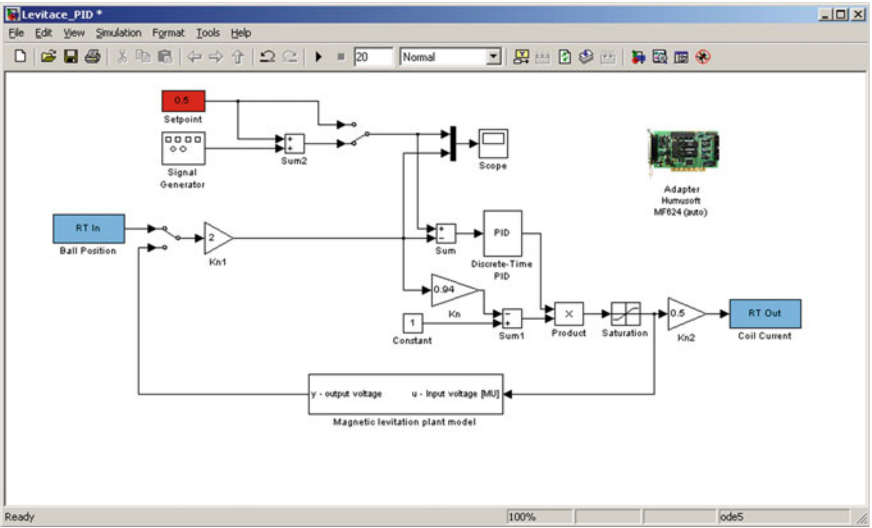

Fig. 4 PID control developed by the magnetic levitation model producer

Fig. 8. We see that the control process is much better than the PID control results (compare with Fig. 5). The controlled process is still very sensitive, the control accuracy is not ideal, but the problem with the stability has been mostly eliminated thanks to the LFLC control properties.

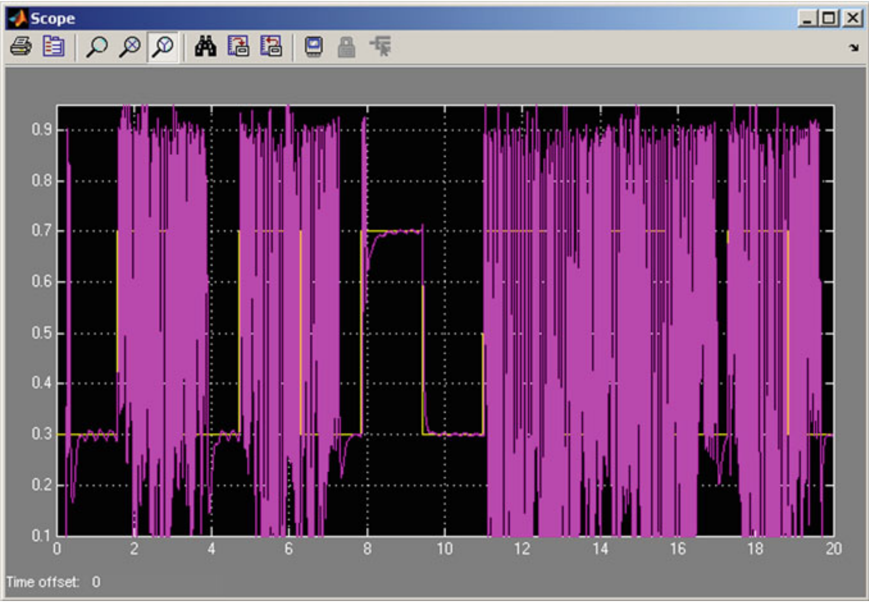

Fig. 5 PID control result

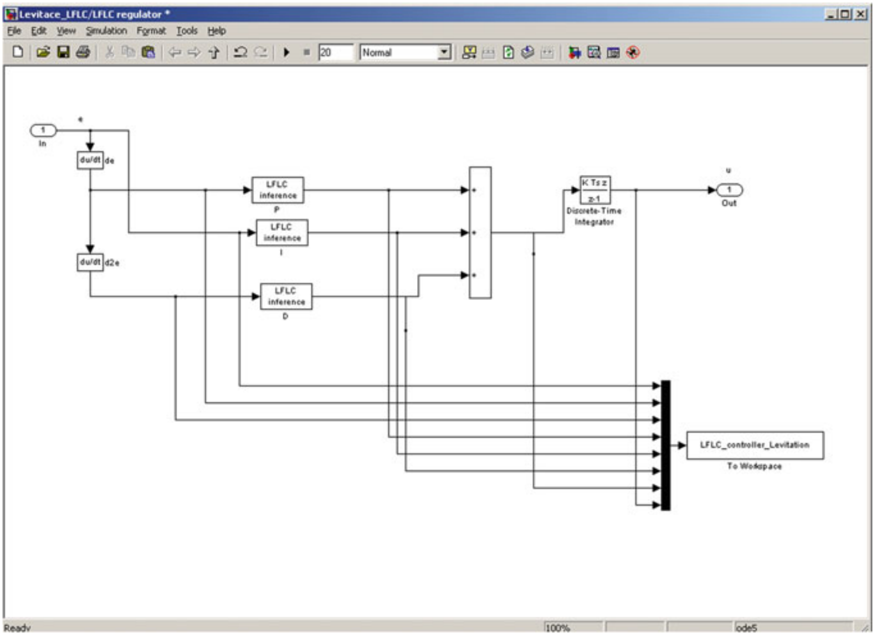

Fig. 6 LFLC controller developed for the magnetic levitation model

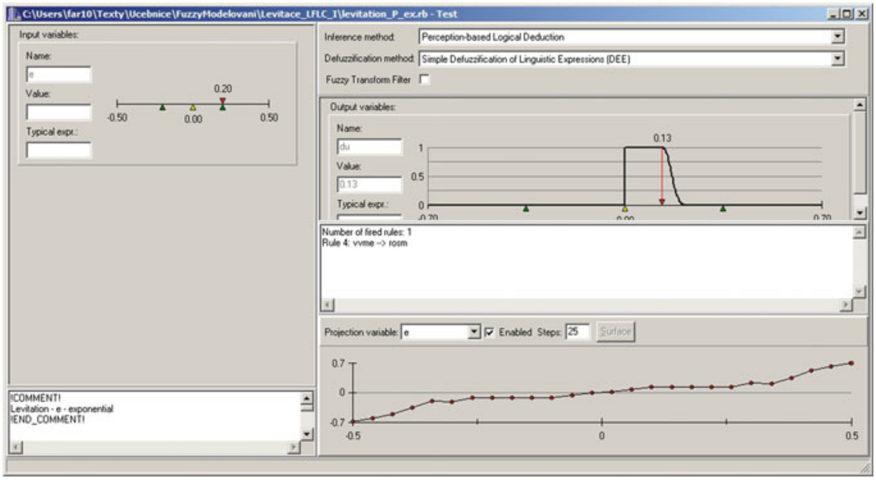

Fig. 7 LFLC controller behavior

Table 1 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	$-40{,}000 \div 40{,}000$	0.03	$-1{,}200 \div 1{,}200$

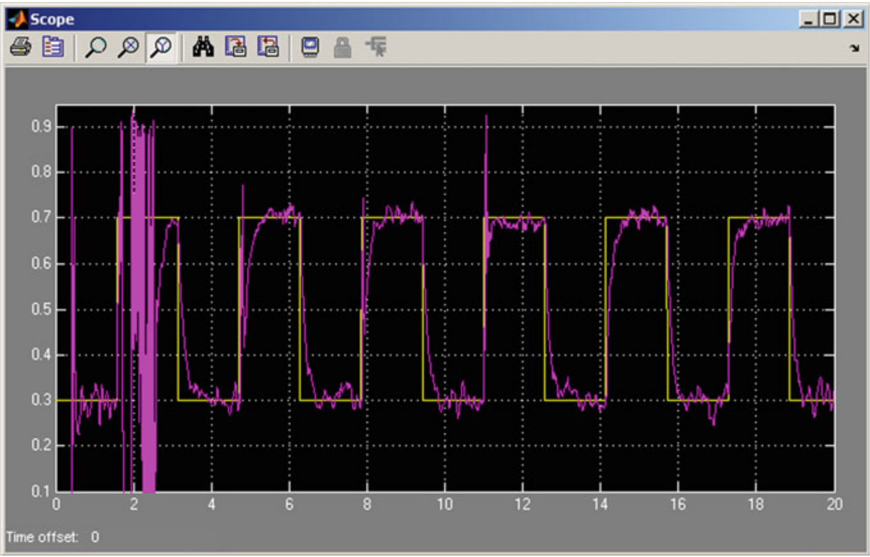

Fig. 8 LFLC control result

3 Conclusions

The presented example of LFLC use has been solved at the University of Ostrava. It is obvious 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. 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 magnetic levitation model. Having completed these projects, students are able to define control strategies based on LFLC for any similar controlled system [9, 10].

Acknowledgements This work was supported by the European Regional Development Fund in the IT4Innovations Centre of Excellence project (CZ.1.05/1.1.00/02.0070) and during the completion of a Student Grant (SGS15/PřF/2014) with student participation, supported by the Czech Ministry of Education, Youth and Sports.

References

1. Zadeh, L.A.: Fuzzy sets. Inf. Control **8**, 338–353 (1965)
2. Zadeh, L.A., Kacprzyk, J.: Fuzzy logic for the management of uncertainty. Wiley, New York (1992)
3. Mamdani, E., Assilian, S.: An experiment in linguistic synthesis with a fuzzy logic control. Int. J. Man-Mach. Stud. **7**, 1–13 (1975)
4. Takagi, T., Sugeno, M.: Fuzzy identification of systems and its applications to modeling and control. IEEE Trans. Syst. Man Cybern. **15**, 116–132 (1985)
5. Novák, V.: Linguistically oriented fuzzy logic control and its design. Int. J. Approximate Reasoning **12**, 263–277 (1995)
6. Novák, V. Perfilieva, I.: Evaluating linguistic expressions and functional fuzzy theories in fuzzy logic. In: Zadeha, LA., Kacpryk, J. (eds.). Computing with Words in Information/ Intelligent Systems, vol. 1, pp. 383–406. Springer, Heidelberg (1999)
7. Novák, V.: Genuine linguistic fuzzy logic control: powerful and successful control method. In: Hüllermeier, E. and Kruse, R. and Hoffmann, F. (eds.). Computational Intelligence For Knowledge-Based Systems Design, pp. 634–644. Springer, Berlin (2010)
8. HUMUSOFT Web information system 2012 (on-line). Cite 10 Jan 2013. Available on web. http://www.humusoft.cz/produkty/models/ce152/ (2012)
9. Takosoglu, J.E., Laski, P.A., Blasiak, S.: A fuzzy logic controller for the positioning control of an electro-pneumatic servo-drive. J. Syst. Control. Eng. **226**(10), 1335–1343 (2012)
10. Godoy, W.F., Da Silva, I.N., Goedtel, A., Palácios, R.H.C.: Fuzzy logic applied at industrial roasters in the temperature control. In: 11th IFAC Workshop on Intelligent Manufacturing Systems, IMS 2013, Sao Paulo, Brazil, pp. 450–455 (2013)