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FUZZY FUNCTION APROXIMATION IN SIMULATION MODEL

ABSTRACT

The paper deals with utilization of fuzzy logic for simulation model parameter, which is changed during simulation experiment. Additive fuzzy system is used for approximation of continuous functions, whereas the relevant membership functions are based on ellipsoidal rules. Application of that methodology is demonstrated on the parameter adaptation related to simulation model of an asynchronous machine. The mentioned adaptation depends on the changing magnetic properties.

KEY WORDS

fuzzy logic, simulation model, adaptation, asynchronous machine

1. INTRODUCTION

The aim of the paper is to demonstrate the use of fuzzy logic for the adaptation of simulation model parameter that does not change during the simulation. The paper describes the use of an additive fuzzy system for the approximation of point functions. The method is demonstrated on the adaptation of simulation model parameter in an asynchronous machine.

2. LANGUAGE APPROXIMATION

The function of one or more variables (usually non-linear function) can be approximated by means of a fuzzy system. This type of approximation presents verbal description; therefore, it is called language (linguistic) approximation. Such approximation method brings certain advantages. Firstly, fuzzy approximation allows for the use of quality knowledge (experience, knowledge, heuristics) about the function to be approximated. The second advantage is the characteristic feature of approximation called local sensitivity. In case of a fuzzy system approximation, local adaptation can be reached by a mere change of the appropriate rule consequent. Moreover, the size of such local area to be changed can be influenced by the fuzzy aggregate width within the rule of given antecedent. Functional values within the whole sub-aggregate of the defined approximated function field can be influenced by the adaptation of fuzzy aggregate carrier input variable. The properties of the approximation function can be locally influenced in the same way. The approximation method is described in the following paragraph. One variable function $y=f(x)$ is given within the definition range X and functional values range Y. If x reaches the sharp value of x^*, then $y^* = f(x^*)$. This equation represents a sharp relation $if(x = x^*)\ then\ (y = y^*)$. The approximation is then expressed by a set of rules where each rule covers a part of the approximated function.

3. ADDITIVE FUZZY SYSTEM

The sharp input value x_i of an additive fuzzy system is fuzzified, i. e. aggregate A is made. Such an input fuzzy aggregate indicates an output fuzzy aggregate B'

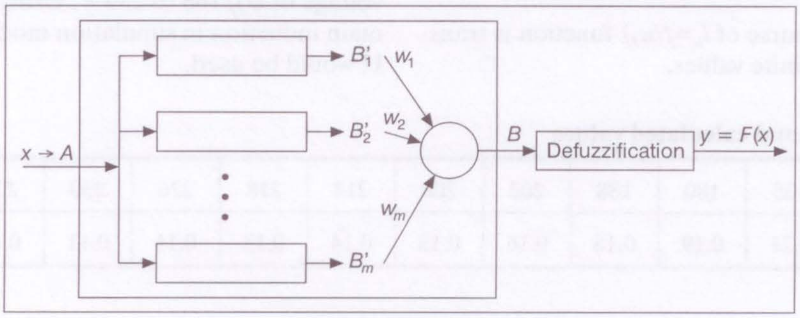

Figure 1 - Additive fuzzy system

at each fuzzy rule output. The results of all the rules are aggregated into the resultant fuzzy aggregate *B*, which is then defuzzified (Fig. 1).

4. MAMDANI TYPE FUZZY SYSTEM

It is a fuzzy system described by the following rules. Let us have a non-linear function of more variables

$$y=f(x_1, x_2, \ldots, x_n) \quad (1)$$

to be approximated by a fuzzy system. The input variable is defined at universe *Y*; input variables x_i at universe X_i. Universe *Y* is covered by fuzzy aggregate set B^j and by universe X_i, fuzzy aggregate sets A_i^j. Non--linear function *f* can be approximated by a fuzzy system with file *r* of the rules type

$$\text{if } (x_l = A_l^{j_k}) \text{ and} \ldots \text{and } (x_n = A_n^{j_k}) \text{ then } (y = A^{j_k})$$
$$k = 1, 2, \ldots, r, \quad (2)$$

where *k* is the rule number and *r* is the number of rules.

5. ADAPTATION OF SIMULATION MODEL PARAMETER IN AN ASYNCHRONOUS MACHINE

When compiling an asynchronous machine model, its parameters are usually considered to be fixed. This results in incorrect simulation. One of the parameters of the machine is the main induction L_h, which depends on magnetic loading of the ferro-magnetic circuit of the machine.

5.1 Fuzzy system setup

To set up a fuzzy system, the measured and calculated immediate voltage values and main induction of a non-load asynchronous machine are taken as the range of the input and output variables at supply voltage f = 50 Hz.

In a fuzzy system setup it is essential to carry out the following:

- fuzzification – course of $l_h = f(u_l)$ function is transferred into indefinite values,
- to determine the evaluation criteria based on given criteria, the output values are determined from the input indefinite values,
- defuzzification – indefinite output values are transferred to the output quantity.

5.2 Fuzzy approximation and data-based rules determination

To record the time alterations of the modeled system, we use a cognitive fuzzy map that is explicitly oriented on dynamic systems modeling and on the expertise. This approach is viewed as a fuzzy rule system based on standard additive model.

The real input *x* simultaneously activates the *m* antecedents of the rules; weighted consequent values then provide for the output value *y*. The inputs and outputs are interlinked in the structure.

Rules construction has been carried out in expert way, and the following rules have been observed:

- triangular (trimf) or trapezoid (trampf) classification,
- number of classifications is determined to cover the input and output variables,
- Mamdani fuzzy rules system is used,
- each value in the range of input variables belongs to min. one up to max. two fuzzy aggregates (Fig. 2, Fig. 3).

6. CONCLUSION

The use of a fuzzy system for the adaptation of selected simulation model parameter, i. e. an asynchronous machine, results in a more precise simulation. The model is designed in Matlab environment, module Simulink, where the testing was carried out. The results of testing have been verified by means of comparison with measured values at a real machine. The presented sample of a simulation model demonstrates that the main induction L_h value changes within the range of 0.22 to 0.08 H, corresponding to the stator voltage of U_{1f} 168 to 250 V. Using a fixed value of the main induction in simulation model, the value of 0.11 H would be used.

Table 1 - Measured and calculated values

u_{1f} [V]	168	135	180	188	202	208	214	218	226	230	237	244	250
l_h [H]	0.22	0.21	0.19	0.18	0.16	0.15	0.14	0.13	0.11	0.11	0.10	0.08	0.08

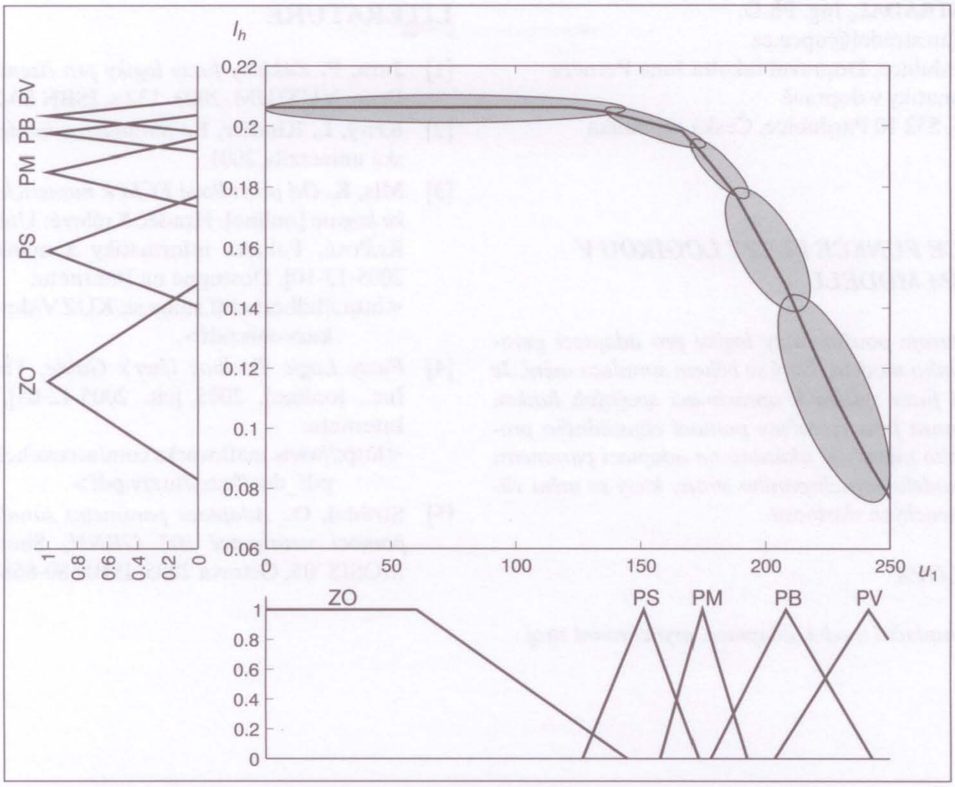

Figure 2 - The projection each ellipsoid on o the axes of the input output state space defines a fuzzy set

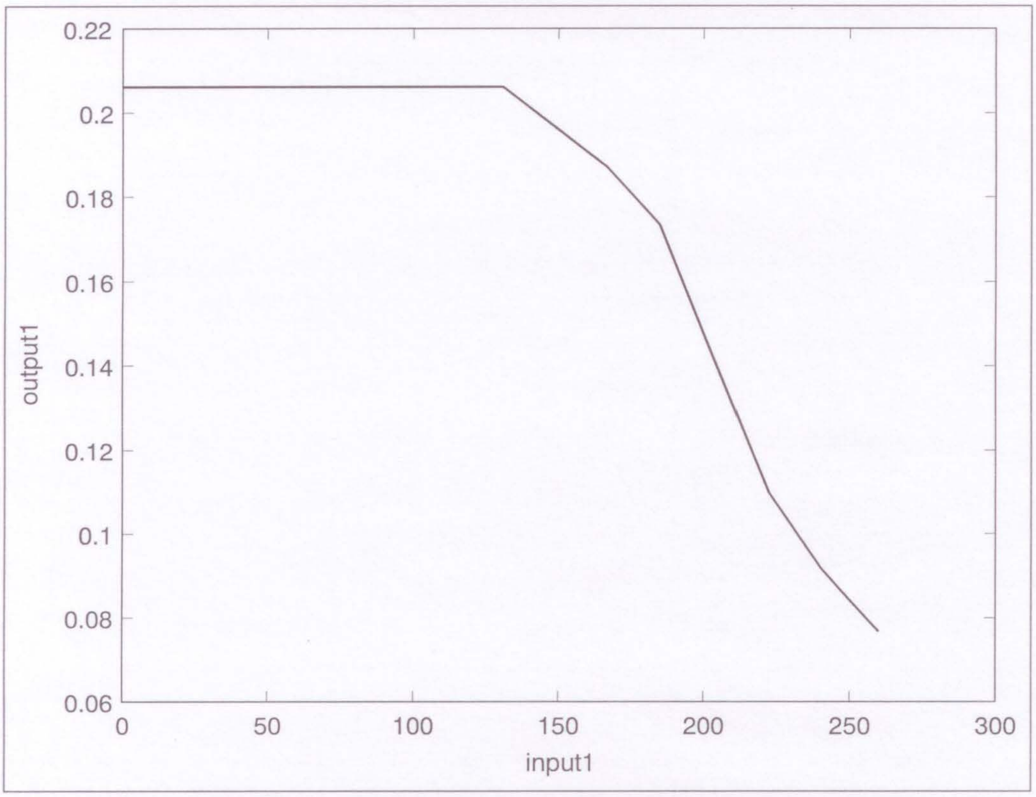

Figure 3 - Dependence of output fuzzy system variable on input variable

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ANOTACE

APROXIMACE FUNKCE FUZZY LOGIKOU V SIMULAČNÍM MODELU

Článek ukazuje použití fuzzy logiky pro adaptaci parametru simulačního modelu, který se během simulace mění. Je použit aditivní fuzzy systém k aproximaci spojitých funkcí, funkce příslušnosti jsou vytvořeny pomocí elipsoidního pravidla. Použití této metody je ukázáno na adaptaci parametru simulačního modelu asynchronního stroje, který se mění vlivem jeho magnetických vlastností.

KLÍČOVÁ SLOVA

fuzzy logika, simulační model, adaptace, asynchronní stroj

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