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A PROBABILISTIC-FUZZY SYSTEM APPLIED TO MODELING OF TIME SERIES

Abstract: The paper describes an approach to modeling times series using probabilistic-fuzzy system. Results of prediction for experimental data are compared with the results obtained from fuzzy inference system FIS and neuro-fuzzy system ANFIS.

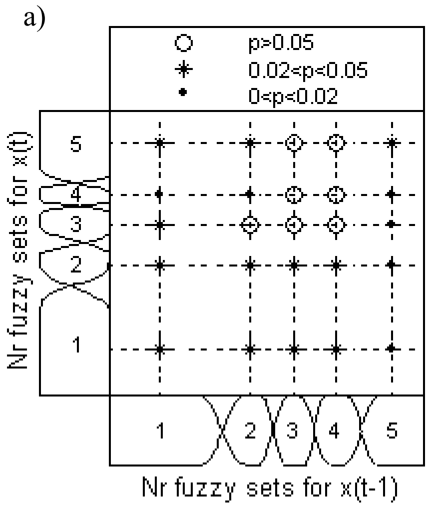
Introduced by Box and Jenkins analysis of time series has been useful tool in many issues of prediction, control, planning and making a decision [2]. Knowledge-based systems with fuzzy rules use time series to build fuzzy models of dynamical systems. Those models, in comparison with classical, nonfuzzy ones, enable to model nonlinear time series taking expert knowledge about an analyzed process into consideration. Remarkable are the tools, which not only use a linguistic knowledge, but also enable to tune given model parameters with empirical data. One example, mentioned in Ref. [1], is a probabilistic-fuzzy inference system (P-FIS). Its methodology for modeling and inference are described in Ref. [3].

The usefulness of the methodology is analyzed with using data about light fraction shares of coal grains (x), where $x \in X \in [0,1]$. The prediction of this parameter is not trivial owing to heterogenic material and random factor at sampling. In the paper, there is described an approach to prediction $x(t)$ at time t as calculations from the model on a basis of the measurement $x(t\text{-}1)$. Both training and checking data sets include 245 data values each.

The P-FIS parameters are selected to provide a lowest prediction error, which is expressed by RMSE (Root Mean Squared Error). Grid partition and fuzzy c-means clustering are used to construction membership function of fuzzy sets. In case of wrong matching parameters of fuzzy sets, the prediction brings nearer to average of measurements. As a result, the optimal system structure is a model with 5 membership functions type PI for each input and output (Fig. 1a) and the minimum as a fuzzy implication. Then, the probabilistic-fuzzy system generates 25 elementary rules with nonzero weights. An exemplary file rule is in the form as follows:

(w_1= 0.32) **IF** (x(t-1) IS *Mf11* **THEN** (x(t) IS *Mf21* ($w_{1/1}$=0.1376)) **ALSO**
(x(t) IS *Mf22* ($w_{1/2}$=0.1396)) **ALSO** (x(t) IS *Mf23* ($w_{1/3}$=0.1818)) **ALSO** (2)
(x(t) IS *Mf24* ($w_{1/4}$= 0.1909)) **ALSO** (x(t) IS *Mf25* ($w_{1/5}$= 0.3501))

where w_1 presents the marginal probability of fuzzy events P(*Mf11*) and $w_{1/j}$ (j=1,…,5) states the conditional probability of fuzzy events occurring in rule conclusion. Fig. 1a presents the joint probability distributions of fuzzy events. The distribution is used in calculating the weights in the model rules.



b)

	Error RMSE		Number of rules
	For training data	For checking data	
FIS	0.1624	0.1726	5
P-FIS	0.1091	0.1209	25
ANFIS	0.0960	0.1558	26

Fig. 1. Result of analysis: a) the probability distributions of fuzzy events obtained from P-FIS system , b) comparison of RMSE for various fuzzy systems.

The prediction errors of the P-FIS system are compared with results obtained from another nonlinear predictor (Fig. 1b). Parameters of fuzzy sets for FIS and P-FIS systems are constructed using the same initial conditions for fuzzy c-mean clustering. It is remarkable, that taking the weights of the fuzzy rules (2) into consideration, may improve the possibility of modeling an analyzed time series. Moreover, comparing results of prediction in P-FIS and ANFIS systems, MAPE (Mean Absolute Percentage Error) value is 2,73% greater for training data of P-FIS system, but 5,02% smaller one for checking data. It showed that in this case P-FIS has better quality of generalization.

However, in order to decrease the prediction error, given time series should be also analyzed using more past values of process and changing the time delay value.

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