SYSTEM MODELLING AND DECISION MAKING SYSTEM BASED ON FUZZY EXPERT SYSTEM

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ABSTRACT

They are available many modeling and decision making systems. Some of them are based on statistical methods like time series analysis. The general problem of these systems is that they cannot correctly react to the changes of modeled systems and their environment. This paper presents an approach based on the fuzzy expert system application, which is able to represent the expert knowledge about the modeled system behavior. This approach combines the statistical methods with expert knowledge and is able to give appropriate information about the system behavior and help with the decision making process. The presented paper describes general principles of this system and its application for waste production modeling as a part of the decision making of the company for waste treatment. This company is able to optimize its resources and warehouse stock management to minimize the production costs.

KEY WORDS

modeling, decision making, time series, expert system, fuzzy logic, analysis, optimization, prediction

JEL CODES

C53, C63, Q53

1 INTRODUCTION

Actually, a lot of companies have tried to optimize their systems of warehouse stock management to minimize their production costs. The optimization means mainly optimization of processes like resources adjustment, resources planning, purchasing, deliveries, sales etc. The main goal is clear – not to spend too much money for stock and optimally use their resources. There are various information systems more or less successfully anticipating and predicting the quantity of resources that should be ordered.

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There are generally used different approaches to the sales prediction and thereby the production planning (Brown, 2000; Swift, 2001). These can be equalized on statistical methods, especially the analysis of time series, but in practice we often come across with very simple approaches that are very robust at the same time, such as the method of moving average. Our approach is based on the use of fuzzy logic expert systems (Novák, 1995; Pokorný, 1996). Experts systems, in particular using fuzzy logic are in this area used by a number of authors for different applications (Xu et al., 2010; Zhang et al., 2004; Zhang and Liu, 2005). The applications of artificial neural networks (Vaisla et al., 2010; Vaisla and Bhatt, 2010) or tools of soft computing are also very interesting. As advantage of Rule-Based Expert Systems is a particular opportunity to use the knowledge of experts and their simple expressions by rules. Fuzzy logic then helps us especially with easy expression of dependences among the values which is poorly expressed using crisp values. Practical use of the expert system is the general trend of the observed value (Baker and Canessa, 2015). It shows that in such cases it is appropriate to analyze the general trend using methods based on time series analysis (Jemelka et al., 2015). An expert system will be used to identify the additional value and description of the dynamic system behavior. This approach is described in this paper.

2 TIME SERIES ANALYSIS

An example of the application of an expert system for prediction of waste production in local area (CSU Prague, 2014) of the city of Ostrava is shown. We have waste production data for each of the weeks in the year 2016 (OZO Ostrava, 2016), split into two parts. We have used the data for odd pairs of weeks to determine the knowledge base. The remaining data, then we have used to verify the behavior of the expert system compared to the prediction based on the moving average method.

The first step is to find out the general trends for all waste groups (paper, plastic, and mixed waste). The standard optimization method of least squares will be used to identify the major trends. We will use discrete time kT, where the time period is $T =$ pair of weeks, $k = 0, 1, 2, \ldots$ for the independent axis. After deduction of major trends we obtain data for the expert system.

3 FUZZY EXPERT SYSTEM DESIGN

The first task is to determine the parameters of the rule-based fuzzy expert system. From previous works, we have already known that the more parameters affecting the waste production we can describe, the more accurate the prediction is, see for example Farana et al. (2017). Thus, as the parameters we set the waste production of individual waste types in the previous two weeks and some known parameters influencing the waste production positively (special event) or negatively (holidays). For the realization of the expert system, we will use the Linguistic Fuzzy Logic Controller (LFLC; see Novák, 1995), which is very convenient for practical applications.

LFLC is the result of the formal theory application 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 high, medium, deep, about thirty-one, roughly one thousand, very long, more or less deep, not very tall, roughly cold or medium warm, roughly strong, roughly medium important, and many others. They form a small – but very important

– constituent of the 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:

$$\langle \text{linguistic modifier} \rangle \ \langle \text{TE-adjective} \rangle, \tag{1}$$

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).

A very important feature is the possibility of setting the context of individual variables and use the assembled knowledge base for a different range of values, see Fig. 1.

This set of linguistic expressions has been drawn up on the basis of the experience of the experts, but it does not always suit the particular situation. The frequency of each value shows that most of the values are concentrated in the middle of the interval, which covers little linguistic expressions, so when compiling a system of rules for the expert system, there have often appeared the same values (ze). LFLC tool offers the possibility of user-set assembly of evaluative linguistic expressions that will better respond to the current situation.

Now we are able to set-up knowledge base describing the standardized system behavior based on previous values and identified parameters. For technical reasons, input and output values must be shifted so that we work with positive numbers only. Thus we have the system ready for subsequent modification of contexts according to the major trend.

Below, examples of the IF-THEN rules of the expert system are presented:

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IF(SEASON IS SUMMER) AND
(PAPER_PREV IS HIGH) AND
(HOLIDAY IS SMALL) AND
(EVENT IS VERY HIGH) THEN
(PAPER IS MEDIUM)

IF(SEASON IS SUMMER) AND
(PLASTIC_PREV IS HIGH) AND
(HOLIDAY IS SMALL) AND
(EVENT IS VERY HIGH) THEN
(PLASTIC IS VERY HIGH)
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4 EXPERT SYSTEM VERIFICATION

As already stated, the set of rules has been drawn up on the basis of waste production data from the year 2016. Data for odd pairs of weeks has been used for expert system learning, data for even pair of weeks was used for expert system verification. We can see that compared to the moving average (of the four previous values), the expert system reaches an average quarter a deviation from the true value. There is mainly involved in knowledge about the influence of different parameters on the system behavior, which were stored in the knowledge base.

5 CONCLUSION

The paper has introduced a very advantageous combination of conventional methods known from the data series analysis, which enabled to identify the main development trend of the system. The follow-up expert system made it possible to describe the influence of various parameters on the final output value of the system and therefore achieved very good estimates of the system further development. This approach was validated with real data from the local territory waste production and showed the correctness of the presented methodology.

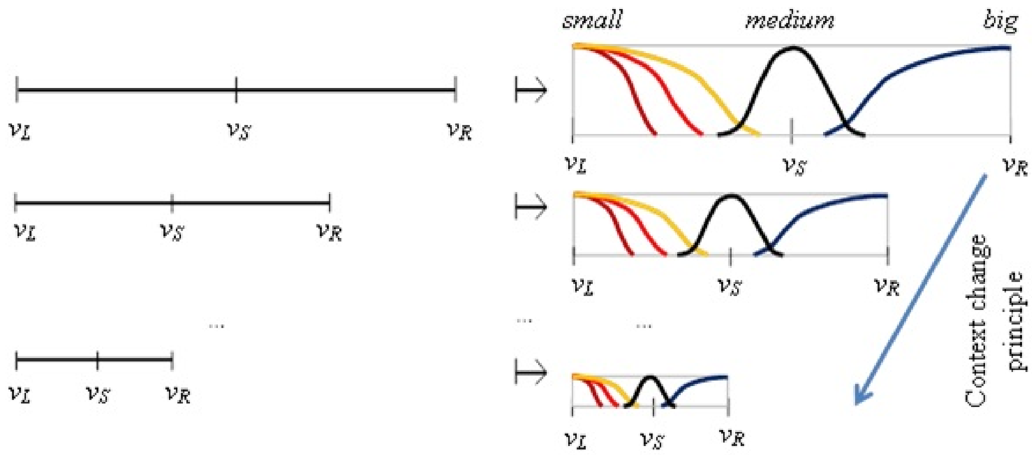

Fig. 1: A general scheme of intension of evaluative expressions (extremely small, very small, small, medium, big) as a function assigning to each context a specific fuzzy set (Novak, 1995) and the automatic context change principle

Tab. 1: Comparison of prediction results – moving averages

	Real data				Moving average			Moving average		
Week	Total	Paper	Plastic	Mixed	Paper	Plastic	Mixed	Paper	Plastic	Mixed
6	3769.6	140.7	269.9	3359.0	170.9	305.2	4291.4	17.7%	11.6%	21.7%
8	3805.4	145.2	286.4	3373.8	178.6	326.9	4339.6	18.7%	12.4%	22.3%
10	3605.3	140.6	277.2	3187.5	183.99	356.8	4428.0	23.6%	22.3%	28.0%
12	3541.3	134.86	258.3	3148.1	189.53	375.1	4341.6	28.8%	31.1%	27.5%
14	3406.3	145.11	267.68	2993.54	189.18	369.3	4220.6	23.3%	27.5%	29.1%
16	3635.06	144.32	280.36	3210.38	189.76	364.3	4131.9	23.9%	23.0%	22.3%
18	3711.76	160.77	283.3	3267.66	193.75	365.5	4174.8	17.0%	22.5%	21.7%
20	3655.59	158.51	275.5	3221.6	201.04	372.9	4300.4	21.2%	26.1%	25.1%
22	3780.5	155.81	273.5	3351.23	208.4	375.66	4335.4	25.2%	27.2%	22.7%
24	3807.26	166.75	286.5	3353.98	205.99	371.6	4416.3	19.0%	22.9%	24.1%
26	3798.4	216.6	249.7	3332.0	211.6	373.2	4445.4	−2.4%	33.1%	25.0%

Tab. 2: Comparison of prediction results – LFLC expert system

	Real data				Fuzzy-expert system			Fuzzy-expert system		
Week	Total	Paper	Plastic	Mixed	Paper	Plastic	Mixed	Paper	Plastic	Mixed
6	3769.6	140.7	269.9	3359.0	145	270	3400	3.0%	0.1%	1.2%
8	3805.4	145.2	286.4	3373.8	150	290	3400	3.2%	1.2%	0.8%
10	3605.3	140.6	277.2	3187.5	145	280	3200	3.1%	1.0%	0.4%
12	3541.3	134.86	258.3	3148.1	130	260	3200	−3.7%	0.6%	1.6%
14	3406.3	145.11	267.68	2993.54	145	260	3000	−0.1%	−3.0%	0.2%
16	3635.06	144.32	280.36	3210.38	145	280	3200	0.5%	−0.1%	−0.3%
18	3711.76	160.77	283.3	3267.66	160	280	3300	−0.5%	−1.2%	1.0%
20	3655.59	158.51	275.5	3221.6	160	270	3200	0.9%	−2.0%	−0.7%
22	3780.5	155.81	273.5	3351.23	155	270	3400	−0.5%	−1.3%	1.4%
24	3807.26	166.75	286.5	3353.98	170	280	3400	1.9%	−2.3%	1.4%
26	3798.4	216.6	249.7	3332.0	230	260	3400	5.8%	4.0%	2.0%

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