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APPLYING MULTIFACTOR LOGICO-PROBABILISTIC FUNCTIONS IN LOCAL ECOLOGICAL MONITORING

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ABSTRACT
The ecological monitoring involves the activities of observing, analyzing, and controlling. The purpose of the present report is to propose a system for observing a natural water reservoir within the boundaries of a settlement. The quantity and quality of hazardous emissions according to the productivity of local enterprises and changes in atmospheric conditions will be monitored. The plant considered is a multifactor and stochastic one. For this purpose multifactor logico-probabilistic functions have been used.

INTRODUCTION

The ecological monitoring is a system of observing, analyzing, and controlling the impact of one or more pollutants on the state, properties, and modifications of biosphere parameters. It is important to measure the quantitative values and control the qualitative indicators that characterize the environment components: water, air, soil, landscape, flora, and fauna. These components are basic for the subsystems of ecological monitoring – water, soils, radioactive pollution, noise and vibrations, non-ionizing emissions, forest subsystems, preserved natural sites, air, etc.

In settlements with developed industry it is especially important to monitor these parameters and to define in time the level of pollution. There exists a hierarchical system for ecological monitoring, in which the environment pollution data are forwarded by the Regional Inspection for Natural Environment Protection (RINEP) to the Ministry of Environment and Water (MEW) and the Central Dispatching Station [3]. There are still some problems that are as follows:

- Low level of automation in monitoring the environment parameters [4];
- All technical devices for measurement should have unified metrological characteristics [4];
- Low level of the communication system [4];
- Lack of system approach to the investigation of ecological plants [4];
- Sudden large-volume release of pollutants performed by industrial enterprises.
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All factors listed so far define the processes of polluting the environment as stochastic and non-linear. Furthermore, in a given region there are more than one enterprises releasing pollutant substances. This leads to multifactorness of the problem for forecasting the possible pollution.

The local ecological monitoring involves considering the extent of water pollution in a settlement. The output level y(t) will be forecasted for preset varying input or disturbing actions, x(t) or z(t) respectively. All these have unknown probabilistic characteristics.

The objective consists in determining the logic functions of the relationship between input and output parameters, taking into account the disturbances. In such a way this relationship will allow forecasting the behavior of the plant, which in this case is the water pollution of a natural water source in a settlement.

PROBLEM DESCRIPTION

The generalized technological diagram of the processes of releasing hazardous substances into the river is shown in Fig. 1.

The input factors are: $x_1(t)$ representing various types of organic pollutants from the first enterprise, given in mg/l, $x_2(t)$ representing varies types of inorganic pollutants from the first enterprise, also given in mg/l, $x_3(t)$ being the water flow rate from this enterprise, $x_4(t)$ the organic pollutants from another company in mg/l, $x_5(t)$ inorganic pollutants, $x_6(t)$ being the flow rate. The factors listed above depend on the company's productivity rate as well as on the qualitative change of the raw materials being used. For instance, in the cosmetics and chemical industries the qualitative characteristic of released hazardous substances depends on the type of products being manufactured at the corresponding point.

Of course, the input flows of materials can be generated by several enterprises if there are such in the region of investigation. Moreover, the probability that RINEP does not acquire data for pollutants from any large or small enterprises should be also taken into consideration. In such cases it will be useful to examine the activities of small companies and workshops in order to find out the approximate qualitative and quantitative compositions of released pollutants.

An important factor affecting essentially the model being developed is the detection of the place where polluted water is poured out into the river. In most Bulgarian cities there are separated industrial zones where all manufacturing enterprises are located on a territory appointed for these purposes. There are also places where these are located all over the settlement. When there are industrial collectors at different locations, in some cases exceeding the acceptable limit values will be prevented.

Besides, the time point of waste release should be taken into account as well. In cyclic technological processes more hazardous substances are released at the end of each cycle. This is the case with the pharmaceutical and cosmetics companies where various containers are washed at the end of shifts. Respectively, in enterprises having a waste water treatment station the occurrence of this event is well known and an increased amount of reagents is added at that moment.

Disturbing factors acting upon the pollution of the ecological plant, i. e. the river, turn out to be: $z_1(t)$ being the amount of precipitation during the period of sampling, $z_2(t)$ the water temperature, and $z_3(t)$ the water speed in the river. These factors are of stochastic nature and influence to a great extent the output parameters. Precipitations increase the river flow rate, and level of hazardous component content, measured in mg/l. becomes lower. On the other hand, it should be taken in mind that in time of raining many companies discharge polluted water for then it is almost impossible for the inspections to corner such offenders. The temperature is an essential parameter because some substances decompose more quickly with its increase. The speed of water movement exerts the same effect: rapid waters have a higher content of oxygen and volatile substances decompose faster.

Output factors to be forecasted are: $y_1(t)$ being the water flow rate in the river, $y_2(t)$ the quantity of hazardous components in the river, and $y_3(t)$ the water turbidity.

The main links between input and output flows are also shown in Fig. 1. The effect exerted by disturbing factors has not been added intentionally because these influence all the outputs.

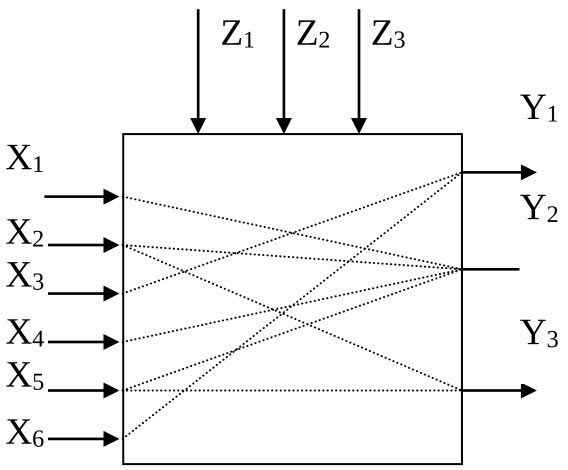


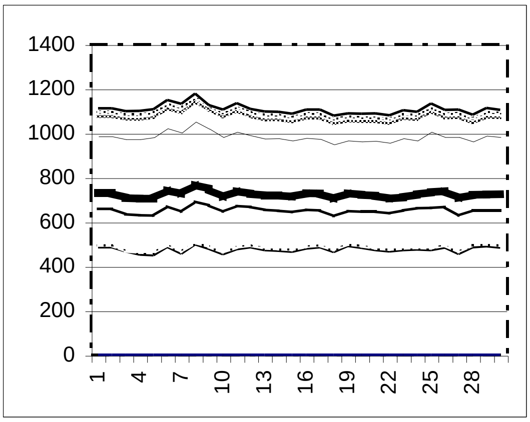
Figure 1

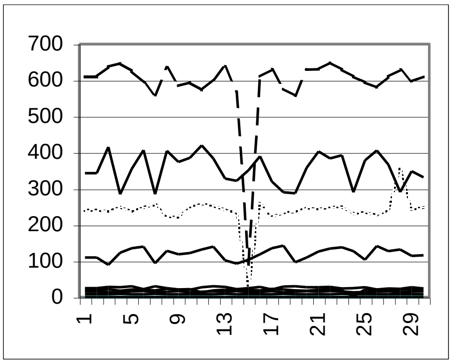
POSSIBILITIES PROVIDED BY THE MULTIVALUED LOGICAL PROBABILISTIC FUN

Analyzing the parameters listed above shows that they are multiple and that it is difficult to elaborate a precise mathematical model of river pollution resulting from the operation of several enterprises, provided that production and climate conditions are changing incessantly, i. e. the plant is characterized by stochasticity and multifactorness. There are some possible ways of solving this problem:

1. Applying mathematical models to modeling the processes of plant pollution. Using these models leads to complex sets of equations, which, in some cases, do not express all the links existing between the factors. This is the so-called principle of non-compatibility between the plant's complexity and the possibility of achieving high accuracy in its mathematical description.
2. Composing a logico-probabilistic model (LPM) when a large set of plant's inputs and outputs is known. In such a LPM will demonstrate the logical links between the individual variables. However, the extent of interaction between them will not be expressed quantitatively. For multiple changes of a part of the quantities measured or of all of them, when not all feasible possible outputs are known, it is possible to use learning systems (neuron nets).
3. Composing a LPM again and using the simulation product MATLAB represent another possible method of generating the probable outputs.
4. Unfortunately, it is difficult to find out some of the logical relations between factors in the ecological обект considered. This is due to the fact that some of the factors do not influence one another. That is why it can be generalized that the object considered is characterized by fuzzy and stochastic non-determination. As a result it is not possible to apply autonomously methods of the fuzzy logic or those of the probabilistic distributions. [2]

In supporting the above statements data for the inorganic pollutants from two mines are presented as an example:





The plotted graphs clearly demonstrate that in the first graph there are peaks on two of the values that do not depend on the rest of the values. There could be several causes for this phenomenon: due to season precipitations the quantity of filtrated water is higher and the concentration of ingredients is lower; an error in taking and preserving the sample; incorrect method of analysis or device failure; unintentional mixing of samples, etc. Under other unpredictable conditions it is possible that this influence will be expressed in other components or in all of them at the same time.

On the second graph it can be seen that the values of pollutants exhibit certain regularity and are not affected by random influences.

In such cases it is expedient to apply complex methods combining features of the methods mentioned above. Such are the multivalued logical probabilistic functions (MLPF). In these fu

ctions, each parameter assumes several definite linguistic values depending on the accuracy required. The values of the logical arguments are of qualitative character, for instance: very low, low, medium, high, and very high values, i. e. к = 5, which is the exponent of the possible solutions of this problem. In the k-value logical system each element of the argument domain is associated with к elements from Y_j, j = 1 ÷ k, for Y = f(X,W).

Determining the logical values of arguments always takes into consideration the real variation limits of the corresponding quantities. These limits are related to the supposed most probable values that can be assumed by the plant under specific conditions. In some cases, when this is imposed by the real conditions, it is allowed that they exceed the maximal acceptable values or are very close to these values. The degree of membership of each linguistic variable is assumed in accordance with these probable values. Furthermore, when MLPF are formed, technological specialists in the respective area always take part with their expert statement in determining the mutual influence of individual parameters. Table 1 is an exemplary table containing logico-linguistic values of the variables, i. e. of the arguments and function. Only a small part of the feasible combinations is shown in this table.

Table 1.

s	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
x1	VL	L	M	B	VB	VL	L	m	B	VB	VL	L
x2	VL	VL	L	L	M	M	B	B	VB	VB	VL	VL
x3	VL	VL	VL	L	L	L	M	M	M	B	B	B
x4	VL	VL	VL	VL	L	L	L	L	M	M	M	M
x5	VL	VL	VL	VL	VL	L	L	L	L	L	M	M
x6	VB	VB	VB	B	B	B	M	M	M	L	L	L
w1	VB	B	M	L	VL	VB	B	M	L	VL	VB	B
w2	VB	VB	B	B	M	M	L	L	VL	VL	VB	VB
w3	VB	VB	VB	VB	B	B	B	L	M	M	M	M
y1	VL	VL	L	M	M	M	M	M	M	M	M	M
y2	L	VL	M	L	L	L	L	M	B	B	L	M
y3	VL	VL	M	VL	VL	VL	L	M	B	M	VL	Mc

The set of arguments X_i, for i = 1 ÷ n, W_s, for при s = 1 ÷ l and the set of function Y_j, for j = 1 ÷ k have values in the к-element set of logical values Aк (a1, a2, a3 .....$a_к$). [1]
Using probability matrix $P = [p_{sj}]$ the probabilistic correspondence between arguments X_i, for i =1 ÷ n, W_s, for s = 1 ÷ l and the values of function Y_j, for j = 1 ÷ k, where s = 1 ÷ M is the number of the set, is preset. The number of possible sets is $M = k^n$. The function assumes the form:
y=f(X,W)/P{X,W}

In such a way the MLPF expresses the links between individual input, disturbing and output variables, and it will help establishing the logical connection between them. Matrix P{F(X,W)} is represented in the form of a table (Table 2). The table values are based on the variants in Table 1.
2. The relationships between the functions and arguments Y=f(X,W) are derived from Table 2, i. e. the table form is transformed into analytical one. A set of relationships is obtained:

$Y_{i1}=f_1(X_1, X_2\ X_3 \ldots X_n, W_1\ W_2\ W_3 \ldots W_l)$
$Y_{i2}=f_2(X_1, X_2\ X_3 \ldots X_n, W_1\ W_2\ W_3 \ldots W_l)$
$Y_{i3}=f_3(X_1, X_2\ X_3 \ldots X_n, W_1\ W_2\ W_3 \ldots W_l)$
$Y_{iu}=f_n(X_1, X_2\ X_3 \ldots X_n, W_1\ W_2\ W_3 \ldots W_l)$

The functional relationships can be used for making an evaluation of the probabilities of its realization according to the argument values. In such a way, in accordance with the probability laws the logical probabilistic function assumes the form of a logical function. Here follows an example for a possible functional relationship:

$$Y_{i1} = f_1(X_1.\overline{X_2} \vee W_{1.}W_2) \vee X_3 \wedge \overline{X_5}$$

The minimal and maximal feasible probabilities are determined from the table with the set of arguments. Based on derived logical functions it is analyzed when they are minimally or maximally probable.

CONCLUSIONS

The method described can be used for forecasting the behavior of a multifactor plant characterized by non-determination and stochasticity. In the case considered the pollution of a local plant, namely the river, is forecasted in accordance with the productivity rate of enterprises in that region and the local climate conditions.

The MLPF written in table form provides a lighter variant of searching for the relationships between the input and output as well as of finding possible controlling actions upon the process. For the plant described these are the stoppage of water with norm-exceeding ingredients and its purification in water treatment stations, knowing in advance the necessary amounts of reagents. It is possible to design a system of taking determinate samples that influence one another, which will enhance the reliability of MLPF.

It is appropriate to use the graphs as a basis for forecasting the ecological monitoring in a given settlement. The most effective approach is the MLP one as it permits embracing completely all the factors influencing the environment. Using this approach an accurate and relatively long-term forecast can be achieved.

REFERENCES

Gegov, Emil 1993. “Logico-Probabilistic Method of Modeling Complex Plants and Systems”, Proceedings of St Ivan Rilski University of Mining and Geology, No. 3, Sofia.

Gegov, Emil 1997. “Investigating Multifactor Plants and Control Systems in Conditions of Non-Determination by Using a Multivalued Probabilistic Logic” – National Conference on Automation and Informatics‘97, Conference Proceedings, Vol. 5, SAI, Sofia, pp. 1 - 5.

Radulov, Georgui 1998. “Instruments for Ecological Monitoring and Automation of Polluted Media Purification”, Sofia.

Videnova, I., Stoenchev, S., Todorov, Ch., Karastoyanov, D., Petrov, I., 1997. “Microprocessor Devices for Ecological Monitoring”, SAI, No. 3.

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