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THE USE OF SYNERGIC REGRESSION IN THE VEHICLE MAINTENANCE
POUŽITÍ SYNERGETICKÉ REGRESE V ÚDRŽBĚ VOZIDEL

Abstract

This paper deals with the possibilities of using synergic regression procedures in the maintenance of vehicles, and with modelling of the influence of source elements of this regression. Synergic regression applies methods of synergy to evaluation of the interaction of two or more processes. In case of the maintenance of vehicles this approach can be used for evaluation of the interaction between the vehicle operational task and the vehicle maintenance. On the basis of calculation of the regression coefficients it is possible to predict development in this relationship, and with the model to study the influence of both processes control.

Abstrakt

Tento článek se zabývá možnostmi použití postupů synergetické regrese při údržbě vozidel a možností modelování vlivu zdrojových členů této regrese. Synergetická regrese aplikuje metody synergetiky na posuzování vzájemného působení dvou nebo více dějů. Při údržbě vozidel je možno tento přístup použít pro posuzování vzájemného vlivu provozního nasazení vozidel a provádění údržby vozidle. Na základě výpočtu koeficientů regrese je možné provádět predikci vývoje této vazby a na modelu zkoumat vliv řízení obou procesů.

1 INTRODUCTION

In the case of synergy, taken as a branch of science in relation to the operation of transport systems, we are interested in those applications of synergic theoretic approaches which study cooperative processes with the aim to find out the causes of origin of new qualities. For these processes the result cannot be obtained by a simple summation of properties of the subsystems.

Tab. 1, according to [Daněk, 1993], gives some of the application possibilities for utilizing synergy in transport:

Tab. 1: Application possibilities of synergy in transport.

	Transport questions	Synergy
1.	Development prognosis: • transport volumes • outputs • number of vehicles	The growth laws Synergic regression
2.	Infrastructure changes • drive changes (energy) • technology changes • diffusion of technologies	The growth laws Synergic regression Origin of a new quality
3.	Connections in the system: • systems of various types • interaction of transport systems • connection of the system parameters	Cooperation of processes Symbiotic systems Systems with competitive relations Selection Morphogenesis

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	Transport questions	Synergy
4	Traffic control: • line of cars at the crossings • flows of goods and passengers	Solitons - origin of kinematic waves D

2 COOPERATIVE PROCESSES

To study the origin, development and mutual relations of the parameters of vehicle operation and safety, it is highly advantageous to use consideration possibilities of these processes by way of synergic instruments which describe cooperative processes and their relationship [Szymanek, 2008].

The basic description comes out from the Lotka-Volterra system of equations:

$$\frac{dn_n}{dt} = a_n \cdot n_n + \sum_{j=1}^{p} b_{nj} \cdot n_n \cdot n_j + J_n \tag{1}$$

where:

n_n . quantity (density or any other measurable variable) of an n- type

t ... time

a_n . the factor of own growth (a breeding ratio)

b_{nj} coefficient of interest conflict of n- and j- types

J_n . the source element of an n- process

Sample for two quantities is characterised by this system of equations:

$$\frac{dn_1(t)}{dt} = a_1 \cdot n_1(t) + b_1 \cdot n_1(t) \cdot n_2(t) + J_1$$

$$\frac{dn_2(t)}{dt} = a_2 \cdot n_2(t) + b_2 \cdot n_1(t) \cdot n_2(t) + J_2 \tag{2}$$

3 SYNERGIC REGRESSION

For practical use, however, it is necessary to estimate values of these coefficients by examining the known courses of interacting processes under consideration. This can be done by way of an application of the previously mentioned theories by help of the synergic regression. Knowledge of the course of the evaluated processes in equidistant time sections is a condition.

The regression solving comes out from the Lotka - Volterra system of equations, described by relation (1):

This system can be detailed into the form for p processes under consideration:

$$\begin{aligned}
\frac{dn_1}{dt} &= a_1 \cdot n_1 + b_{12} \cdot n_1 \cdot n_2 + b_{13} \cdot n_1 \cdot n_3 + \cdots + b_{1p} \cdot n_1 \cdot n_p + J_1 \\
\frac{dn_2}{dt} &= a_2 \cdot n_2 + b_{21} \cdot n_2 \cdot n_1 + b_{23} \cdot n_2 \cdot n_3 + \ldots + b_{2p} \cdot n_2 \cdot n_p + J_2 \\
&\vdots \\
\frac{dn_p}{dt} &= a_p \cdot n_p + b_{p1} \cdot n_p \cdot n_1 + b_{p2} \cdot n_p \cdot n_2 + \ldots + b_{pp-1} \cdot n_p \cdot n_{p-1} + J_p
\end{aligned} \tag{3}$$

Modifying this, a system of recurrent equations originates:

$$
\begin{aligned}
&n_{i+1,1} = n_{i,1}(a_1 \cdot \Delta t + 1) + \Delta t \cdot b_{i,12} \cdot n_{i,1} \cdot n_{i,2} + \Delta t \cdot b_{i,13} \cdot n_{i,1} \cdot n_{i,3} + \ldots + \Delta t \cdot b_{i,1p} \cdot n_{i,1} \cdot n_{i,p} + \Delta t \cdot J_{i,1} \\
&n_{i+1,2} = n_{i,2}(a_1 \cdot \Delta t + 1) + \Delta t \cdot b_{i,21} \cdot n_{i,2} \cdot n_{i,1} + \Delta t \cdot b_{i,23} \cdot n_{i,2} \cdot n_{i,3} + \ldots + \Delta t \cdot b_{i,2p} \cdot n_{i,2} \cdot n_{i,p} + \Delta t \cdot J_{i,2} \\
&\vdots \\
&n_{i+1,p} = n_{i,p}(a_1 \cdot \Delta t + 1) + \Delta t \cdot b_{i,p1} \cdot n_{i,p} \cdot n_{i,1} + \Delta t \cdot b_{i,p2} \cdot n_{i,p} \cdot n_{i,2} + \ldots + \Delta t \cdot b_{i,pp-1} \cdot n_{i,p} \cdot n_{i,p-1} + \Delta t \cdot J_{i,p}
\end{aligned}
\tag{4}
$$

Solution of the equation system according to (4) directly in this form cannot be found. For estimation of values of individual coefficients of such modified equations for individual processes it is possible to use numerical methods for solving linear multinominal regression.

Subsequently, values of individual coefficients calculated that way can be evaluated both quantitatively, i.e. by help of their values, and qualitatively, i.e. to characterize their influence on the processes under consideration.

In the case of quantitative evaluation, it is derived from principles and characteristics of the numerical solution. For estimation of individual coefficient values the least square method is used. To ensure credibility of the estimated values the system uses conformity tests which, after specification of a zero hypothesis and significance value, decide on refusal or acceptance of a statistical significance hypothesis.

4 MODELLING OF THE INFLUENCE OF A SOURCE ELEMENT ON COOPERATIVE PROCESSES

Under certain conditions the source element J_n can become a control member of the systems of cooperative processes. In terms of a real system, after intervention from outside of the system the change of a size of the source element of one process makes it possible to influence the course of this process, and in consequence of the synergic processes in the system to influence even the course of the processes bound in the system.

One of the variants of the source element influence is a system with its variable.

Such a system can be generally described by an equation system that comes from (3):

$$
\begin{aligned}
&\frac{dn_1}{dt} = a_1 \cdot n_1 + b_{12} \cdot n_1 \cdot n_2 + b_{13} \cdot n_1 \cdot n_3 + \cdots + b_{1p} \cdot n_1 \cdot n_p + J_1(n_1) \\
&\frac{dn_2}{dt} = a_2 \cdot n_2 + b_{21} \cdot n_2 \cdot n_1 + b_{23} \cdot n_2 \cdot n_3 + \ldots + b_{2p} \cdot n_2 \cdot n_p + J_2(n_2) \\
&\vdots \\
&\frac{dn_p}{dt} = a_p \cdot n_p + b_{p1} \cdot n_p \cdot n_1 + b_{p2} \cdot n_p \cdot n_2 + \ldots + b_{pp-1} \cdot n_p \cdot n_{p-1} + J_p(n_p)
\end{aligned}
\tag{5}
$$

Analytical solving of such a system is not possible. One of the ways of evaluating the influence of the source elements in the systems of cooperative processes is utilization of a numeric model using the system of equations that come from a differential approach as described by (4).

On the basis of the compiled model it is possible to explore influences of the source elements on behaviour of the systems. Possibly, these systems can be used during control of such processes in terms of analysis „what will happen, if ..." so that the processes were realized in required courses.

As a sample a model for simulation of 5 cooperative processes was designed, using the system of equations (5), created in a commonly available environment.

This contribution shows a result of the model for the case of a system with **a variable value of the source element *J*(*n*)**, when the value of the source elements J_i is dependent on the value of the given process. To express their values a similar relationship was used, as in the previous case, defined by:

$$J_i(j+1) = k_{fi} \cdot n_i(j) \tag{6}$$

where:

k_{fi} ratio value of the source element

In the case of the sample solution the ratio value is same for all processes $k_{fi} = 0.01$.

Plots of the processes after the change are in Fig. 1, presented by a dashed line.

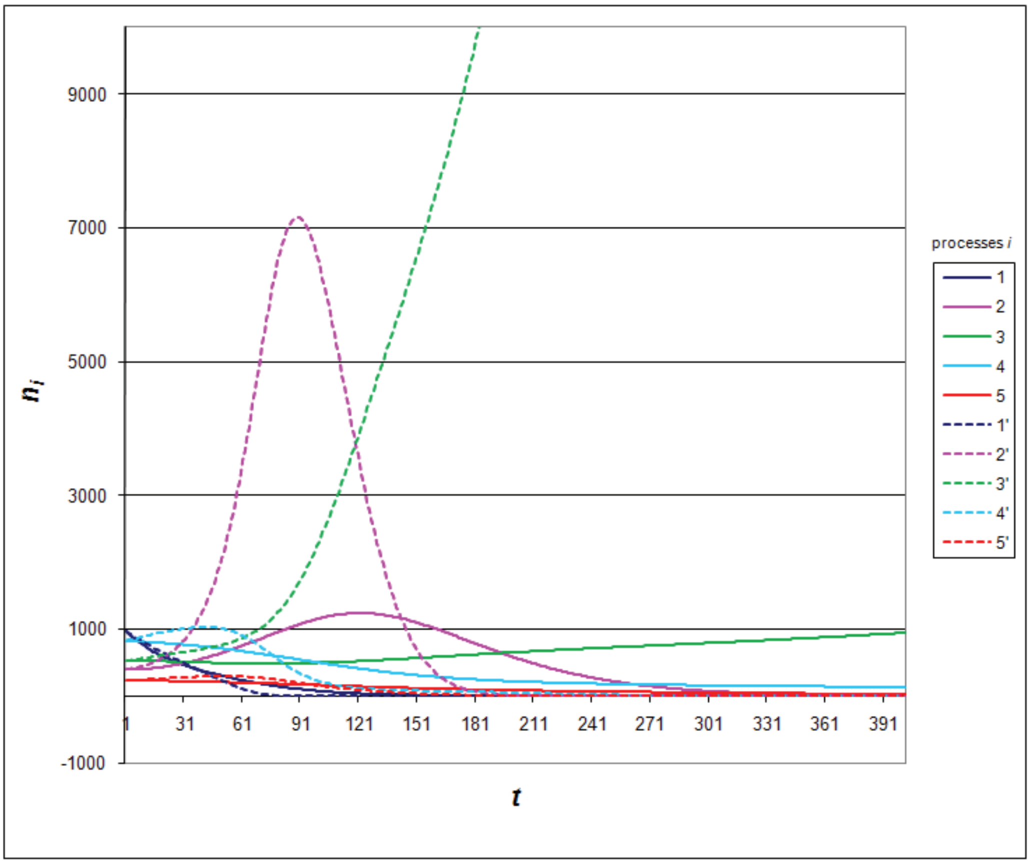

Fig. 1. A model course of the processes for the case of source elements variables.

In this case the model simulation shows that the process no. 2´ reaches a peak and subsequently falls rapidly and, much like the other processes, then becomes fixed. Compared to that, the process no. 3´ gains absolute dominance over the other processes.

5 CONSIDERATION OF THE RELATION BETWEEN THE RAIL VEHICLE OPERATION AND MAINTENANCE

Basic objective characteristics are selected for evaluation of the dependencies between the processes in the maintenance control area, i.e. a daily mileage of a vehicle, a maintenance reserve, number of repair events carried out etc. Using suitable mathematical instruments it is possible to perform their analysis, and on the analysis basis also a certain identification of the processes. Then this is utilized in the control process.

A period of ten days was selected as a basic time interval, to which all characteristics are related. This period is a basic planning period for operative control of the maintenance.

The average daily mileage is specified according to the relationship:

$$L_{DB} = \frac{1}{h}\sum_{i=1}^{h} L_{Di} \text{ [lokkm]} \tag{7}$$

where:

h [1] number of operated powered vehicles

$L_{D\,i}$ [lokkm] a daily transport output of the powered vehicle

Coefficient of the run reserve K_{PR} is given by:

$$K_{PR} = \frac{L_{PR}}{N_{pr} \cdot L_{PP}} \text{ [1]} \tag{8}$$

where:

L_{PR} [lokkm] the run reserve, expresses the difference between the actual transport output and performed maintenance

N_{pr} [1] number of checks within the period

L_{PP} [lokkm] the average mileage of vehicles up to the maintenance event

Results of the regressive coefficient estimation a_{ki} for the system (5) are in Tab. 2. Comparison of real outputs with regressive outputs is in Fig. 2.

Tab. 2: Specified regressive coefficients for the system:

	L_{DB}	K_{PR}
a_{0i}	3945,2636	-0,114850
a_{1i}	0,7242	0,773704
a_{2i}	-0,0341	-0,000041

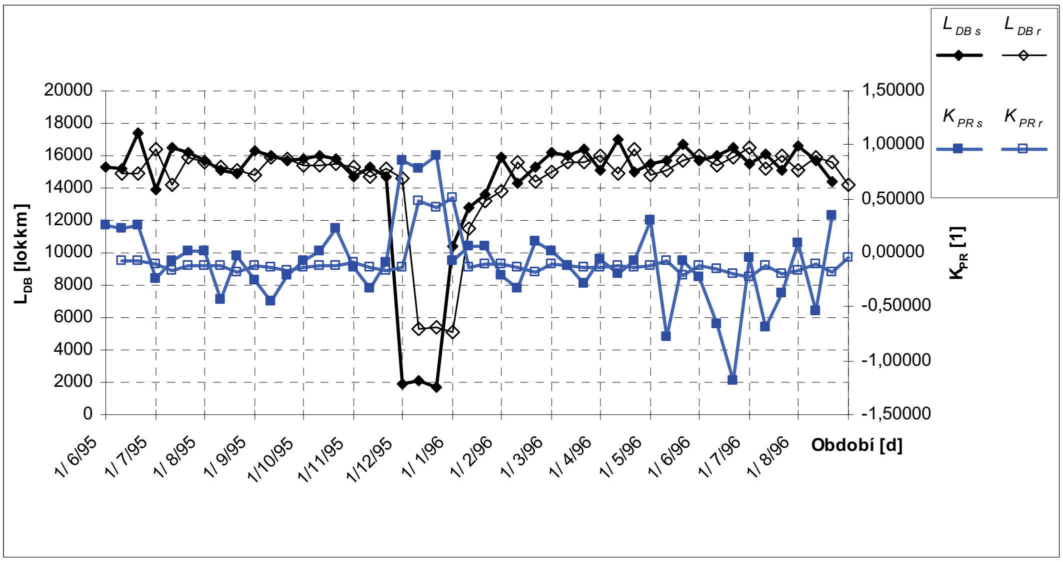

Fig. 2: Comparison of real and regressive outputs
$L_{DB\,s}$ - real average daily run; $L_{DB\,r}$ - regressive average daily run; $K_{PR\,s}$ - real coefficient of the run reserve; $K_{PR\,r}$ - regressive coefficient of the run reserve

6 CONCLUSION

Using the Lotka - Volterra system of equations we can present the methods which enable monitoring of a mutual influencing between the processes. Certain transport systems or transport chains in the interaction can lead towards prevailing of some or the dominance of only one. The processes can be simulated so that their possible development can be monitored. Here we are looking for users in the field of control structures (ministry, transport companies, plants), the instruments can be grants (funds) or, on the contrary, taxes. The assumed processes can be also simulated with the aim of verifying their development in relation to specific values of stimulation or degressive rations.

Nowadays the information technology enables synergic regression on a larger number of co-operative processes, by which a qualitatively new type of information can be obtained, such as breeding ratio, coefficients of collision of interests (both in the size and signs), information about growth, degression or periodicity. Simulation studying, introduction of new elements, such as sources (grants), regressions (taxes), limits or tightness (N_i+N_j=konst.) enable searching of their particular sizes with the purpose to achieve required effects

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