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B.A. Lazurenko

European University Cyprus, Republic Cyprus, Nicosia

PECULIARITIES' OF SYNERGETIC APPROACH IN COMPLEX SYSTEM ANALYSIS

Synergetic approach to complex systems analysis allows us to estimate its demeanor in uncertain conditions. Studying cooperative actions of various sub-systems show that in result of those actions the new structure is formed at macroscopic level with corresponding operations with focus on mathematic modeling of phenomenon's and processes with similar structure in both technical and humanitarian areas. Those originating models have features of spontaneous evolving open systems which allow search of effective ways of controlling those systems from synergetic analysis.

Keywords: *synergetic approach, mathematical model, curvilinear system behavior, uncertainty, complex system, self-organization system.*

Introduction

Synergetic is natural outcome of scientific knowledge integration corresponding to modern concepts. A new synergetic models of various natural and social processes allows researchers to formulate quantitative relations between process's parameters, to forecast development trends and to administrate complex systems behavior in uncertain conditions [1]. Those new-formed models have features of spontaneous evolving open systems such as uncertainty and diversity of development paths. It allows us to find effective ways of systems management from synergetic analysis perspective [2 – 5]. Thus mathematic model which is build with synergetic approach allows picturing and scripting the evolution of system of our interest through differential equations.

Problem statement

Synergetic systems are open-ended systems. When elements merge into a system new feature is created inherent only to that system of elements. So the new structure is formed engendering new feature. It means that system is being self-organized. At the same time self-organization means non-linear behavior of the system which leads to ambiguous reactions on outside influences. Non-linearity in mathematics occurs only when equation has several solutions. In this way quadratics have two solutions, cubic's – three and so on. Non-linearity in environs makes itself via multi-variant behaviors when system is facing choice of several future states. And changes in outside exposures correlate with changes in administrative parameters which are part of evolutionary equation of the form [1]:

$$\frac{dY_i}{dt} = F_i(Y_1, Y_2, ...Y_n), \quad i = 1, 2, \ldots, n, \qquad (1)$$

where Y_i – system variable; t – time; F_1 – variables function, (form of which is governed by system's traits); n – number of variables minimally required for description of observable process.

Knowing which parts of complex system are its elements we are able to find that segregated groups of elements are able to form sub-systems of common system. In this way variables Y_i in evolutionary equation (1) describe links between sub-systems. Single variable Y_i symbolizes general characteristics of collective movement of sub-system's elements. Having this vision evolutionary equation is able to model the process of self-organization in complex system. Different interactions between the system and system's environment are given hard accent here. System itself is unable to change its external conditions but it is able to react and adapt in accordance with surrounding powers. Changing values of controlling parameters outside forces take control over the system's behavior. Note that changes in controlling parameters result in straight effect on sub-systems Y_i, but not on elements of the sub-system. Therefore elements of the system will have to spontaneously change their interactions so their collective movement will follow new values of controlling parameters. This is how self-organization in complex system is done.

Purpose of study to find particularities of synergetic approach in analysis of processes and phenomenon's in complex technical and humanitarian systems.

Results

Creation of mathematical model starts from macroscopic variables selection which qualitatively forms and characterizes main links in a system. Than confrontation of proportions is done – main correlations between studied magnitudes which are based on empirical data. Next these proportions are reformed into evolutionary equation. Besides, escalation of any magnitudes at time is proportional to increase of this magnitude less its loses [2]. In this way synergetic approach towards complex systems analysis allows us to estimate observed system's demeanor in terms of uncertainty. Main task in realization of this approach is to build general mathematical model. The biggest uncertainty rates are major affinity of humanitarian studies. As for example in this paper let's have a look at the formulation of general model of advertisement effect on the off-take algorithm.

The process of managing public opinion in order to increase off-take through use of advertising is a com-

plex objective. Complexity here caused by lots of unknown reasons standing behind actions of potential buyers. In result positive image formation for consumer valued properties of good advertised allows dramatically increase in sales of the good.

It should be pointed that description of the system which consists of various sub-systems can be formed in two levels. First level analyses the sub-system and its interaction with environment. Only at this level quantification of sub-systems' interactions. Second level describes statistical demeanor through the use of macroscopic variables. Public opinion is one of these variables mentioned above. This variable can be measured using questionnaires. In the easiest situation we will get two types of response – negative or positive – and all of the potential buyers will have one of the opinions. It should be noted that along with advertisement effect the opinion formation process is also affected by the groups of people with same or different opinion. So the speed of opinion change is increased because of the influence of the group with different opinion and decreases because of the group-with-same-opinion's influence. Advertising process supports change of negative opinion to positive. But factors - as for example presence of ad's of the competitor's product – are blocking positive opinion formation and decreases advertisement's effectiveness. And there is a risk of positively minded customer will change opinion to negative along with the opportunity of negatively oriented potential buyer changing his opinion to positive. In this situation there are 2 extremes. In result of fast changing opinion there is a possibility of one of the two opinions – negative or positive. When positive – advertisement has maximum of effectiveness. In opposite case – advertisement campaign is failed totally. In different scenario there is a possibility of creation of 2 groups of customers with polar opinions so the polarization of society is done and unstable situation is created. In this case groups of customers are resistant towards opinion changes. And it is unknown which of the opinions will be dominating. System is unstable and critical fluctuations [1] in this case will play significant role because they are switching system to stability.

So the process of positive opinion towards goods advertised creation in specific region is done through the increase of quantities' value of buyers with positive opinion about the good itself. Assume there is some amount of goods **y**, and at the time dt, dy of goods is bought. Observations over implications of advertisements show that during the time off-take escalates. Mathematically this escalation is derivative:

$$a = \alpha \frac{d^2y}{dt^2}, \qquad (2)$$

where a – potential effect of advertisement; α – coefficient of proportionality.

Coefficient α generalizes conditions which are beneficial for advertisement creation. The bigger α, is – the bigger will be the effect of advertisement a on off-take. Besides coefficient α has lower estimates in societies where modern advertisement techniques are not frequently used. In economically developed regions coefficient α should have comparatively high values.

Practically the actual process of advertisement influence usually under pressure from various outside factors which are able to benefit or harm ad's apprehension. Those factors can be divided into two groups. Those are factors related to features of product F_1, and factors related to features of the buyer F_2. In this way correlation (2) will take following form:

$$a + F_1 + F_2 = \alpha \frac{d^2y}{dt^2}. \qquad (3)$$

List of actual an factor which affect F_1 and F_2 is usually massive. That's why we take only the main ones which are present in all major sales operations.

In group F_1 between product features affecting apprehension of an advertisement there is its level of affordability for the buyer. Wide accessibility of good devalues actuality of any information about it. That's why for the F_1 group's determinant factor we will take this product's market coverage:

$$F_1 = -\gamma * y, \qquad (4)$$

where γ – proportionality coefficient; y – number of goods.

Coefficient γ characterizes level of accessibility for this good in specific region. The bigger value γ, takes the bigger effect of factors linked to good F_1 features on potential result of an advertisement a. In regions with developed economics value of γ coefficient will be comparatively high. Note that with growth of product's masses in market value of information about it lowers along with results of ads. This influence is shown in equation (4) by adding minus to its right part.

In group F_2 determinant factor is an income level of moderate consumer. This remonstrated as quantity of demand over period of time. Mathematically it takes form of time derivative $\frac{dy}{dt}$. In this way for this group of factors F_2 correlation will take form of:

$$F_2 = -\beta \frac{dy}{dt}, \qquad (5)$$

where β – proportionality coefficient; y – amount of goods.

Because income of moderate consumer lovers over time because of inflation effect we add minus to the right part of equation (5). Magnitude of coefficient β shows how change of income $\frac{dy}{dt}$ of moderate buyer influences the apprehension level of advertisements. In economically developing regions (where inflation has less effect on income) value of β will have low quantities. Therefore equation (3) is now formed as:

$$a - \gamma * y - \beta \frac{dy}{dt} = \alpha \frac{d^2y}{dt^2},$$

and there we get:

$$\frac{d^2y}{dt^2} + \frac{\beta}{\alpha}\frac{dy}{dt} + \frac{\gamma}{\alpha}y = \frac{a}{\alpha}. \qquad (6)$$

This way we have linear heterogeneous differential equation with constant coefficients which are solved in standard mathematical way. Solving this equation will give us number of goods over time relations which were sold because of ad's influence.

$$y = Ae^{-\eta t}\sin(\delta t + \phi_0) + a/\gamma, \qquad (7)$$

where $\delta = \sqrt{\left(4\alpha\gamma - \beta^2\right)/\left(4\alpha^2\right)}$; $\eta = \beta/(2\alpha)$.

Relation (7) shows that if ad's are constant with constant intensity (a = const), dumped oscillation happens around constant value of a/γ..

Therefore alternation of good and bad fazes for ad's apprehension takes place. And oscillation damping happens in accordance with $\exp\left(-\beta t/(2\alpha)\right)$ law.

Comparing relation (7) with oscillating movement law $y = A\sin(\omega t + \phi_0)$, shows that δ is similar with cyclic frequency ω. Involving roll/yaw ratio $T = 2\pi/\omega$, will result in correlation for the period of time in frames of which ad's are apprehended positively.

$$T^+ = T/2 = \pi/\delta = 2\pi\alpha/\sqrt{4\alpha\gamma - \beta^2}$$

In this way alternation of periods with positive and negative apprehension rates takes place. This periods of time are equal and found by the equation::

$$T^{+(-)} = 2\pi\alpha/\sqrt{4\alpha\gamma - \beta^2}\,. \qquad (8)$$

Timing relation for quantity of goods sold realized with help of advertisement effect is show at the fig. 1.

Quantitative values of coefficients α, β and γ, (part of correlation (8)) are found by using already known economic methods while adapting product promotion process in specific region.

Conclusion

Specifications of synergetic approach in economic processes analysis in uncertain environment (which are hardly formalized) are found. From position of synergetic approach effect of advertisement on number of goods sold is made. Therefore mathematical model for valuing this effect was formed. It should be clear that in the foundation of presented method takes place systematic analysis self-developing evolutionary systems with inherent periods of blooming and decay.

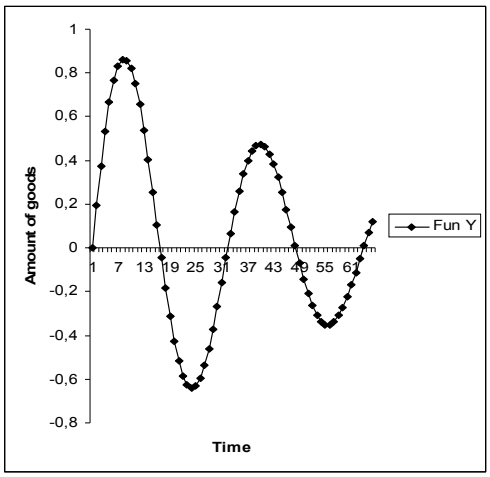

Fig. 1. Effectiveness of advertisement effect on number of units sold

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Рецензент: д-р техн. наук, проф. О.А. Сєрков, Національний технічний університет «ХПІ», Харків.

ОСОБЛИВОСТІ СИНЕРГЕТИЧНОГО ПІДХОДУ ПРИ АНАЛІЗІ СКЛАДНИХ СИСТЕМ

Б.О. Лазуренко

Синергетичний підхід при аналізі складних систем дозволяє визначити її поведінку в умовах невизначеності. Досліджується сумісна дія багатьох підсистем, за результатами якої на макроскопічному рівні виникає нова структура та відповідне їй функціонування. При цьому увага приділяється побудові математичних моделей та явищ, структура яких ідентична для технічних і гуманітарних галузей. Створювані моделі мають якості притаманні само розвинутим, еволюціонуючим відкритим системам, що дозволяє здійснювати пошук ефективних шляхів регулювання з позицій синергетичного аналізу.

***Ключові слова**: синергетичний підхід, математична модель, нелінійна поведінка систем, невизначеність, складна система, самоорганізація системи.*

ОСОБЕННОСТИ СИНЕРГЕТИЧЕСКОГО ПОХОДА ПРИ АНАЛИЗЕ СЛОЖНЫХ СИСТЕМ

Б.А. Лазуренко

Синергетический подход при анализе сложных систем позволяет определить ее поведение в условиях неопределенности. Исследуется совместное действие многих подсистем, в результате которого на макроскопическом уровне возникает новая структура и соответствующее ей функционирование. При этом особое внимание уделяется построению математических моделей явлений и процессов, обладающих идентичной структурой в технических и гуманитарных областях. Создаваемые модели обладают свойствами, присущими саморазвивающимся, эволюционизирующим открытым системам, что позволяет осуществлять поиск эффективных путей регулирования с позиций синергетического анализа.

***Ключевые слова:** синергетический подход, математическая модель, нелинейное поведение систем, неопределенность, сложная система, самоорганизация системы.*