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Branched Chain Reaction in Complex Social Systems

Annotation: This article is devoted to the modeling of chain reactions, as one of the variants of threshold effects in complex social systems. The social-energy approach and mathematical tools of branched chain reactions in chemistry are used to create the mathematical model. Internal processes in the social system are considered Wiener processes.

Keywords: chain reactions, mathematical modeling, complex social systems, socio-energy approach

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Received: 30 September 2013.

Accepted: 07 October 2013

Funding: This work was supported by grants from the Board President of the Russian Federation (project MK-259.2013.6).

Introduction

Physicists, chemists and representatives of some other natural sciences understand well the meaning of the term chain reaction. However, long enough it is also used relating to community. It is possible to hear about chain reactions from journalists, as well as from sociologists, economists, politics and many others. It is, nevertheless, difficult to find in open scientific literature direct scientific evidence of this effect in community and conditions of its emergence. Most probably, it is connected with the complexity of determination of the social environment parameters, their assignment in principle, because the analogies from the natural sciences use generally accurate figures. In fact, the very meaning of this effect is in the determinacy of parameters and accuracy of their determination. It is impossible to speak without it about the opportunity of prediction such processes and studying conditions of emergence. However, social processes cannot be exactly determined. Parameters that are assigned to a social system are usually sufficient artificial, and by definition, cannot be precise. So how do we use them to determine the effect, for which the slightest fluctuations of its main characteristics can lead to a qualitative change in the state system? In order to cut this Gordian knot, you need to change the approach to the social system and to abandon attempts to assign her own parameters of specialty, trying to determine the status of the given system. On the contrary, we must refer to the parameters indirectly, or distributed across individuals. Indeed, to find out whether there will be a chain reaction in a piece of pure uranium, you're not going to do a risky experiment and try to measure the density of the neutron flux inside him. You will take into consideration the weight and pressure of the environment. After these changes, you will be able to give an exact answer about the possibility or impossibility of a chain reaction. Thus, we did not examine the state of the system directly, but above all the conditions affecting it. Of course, this only makes sense when it is easier to define these terms, rather than the system state. We also should mention that, in general, it is more difficult with the social system than with uranium, because neutrons, unlike humans, do not have free will and the ability to make their own decisions. However, it is possible to take into account mathematically using stochastic equations [1-3], which are able to take into account the fluctuations of the social system with some assumptions.

Overall, what do we offer? What indirect parameters did we talk about?

Our proposed socio-energy approach describes social systems and processes. It is a scalable logical-mathematical tool that combines several different methods. Basically it has a social assessment of the system with the help of specially introduced term of the - "social energy" or Esoc (further simply E) [2-3]. Here, a quantity characterizing the potential of the social system to do the work is meant under this concept. This value is a little bit similar to the energy in its physical meaning, but it gives us a certain freedom in the interpretation of another "unused energy". Consequently it is the imperfect work in the valuation of possible energy of human work, not yet extracted resources, etc. This moment is very important for building the model; because it is necessary for the valuation of the social system to take into account all the factors that can influence it. For example, human work is often the determine parameter in the system and at the same time it is very hard classified in terms of the standard physical concepts.

This parameter allows you to represent intra- and extra-systemic processes such as change or redistribution of energy inside the system and between systems. Also, the same basic principles of systematic approach are used.

Internal processes in the social system are considered Wiener processes. Wiener process - in the theory of stochastic processes – is a mathematical model of Brownian motion (it is described by the Langev in equation) or a random walk in continuous time [1].

In detail about the "socio-energy approach", its mathematical apparatus, nuances and s.o. [2-3, 5-6].

The model of the communication field

Series of numerical experiments on the calculation of changes in the parameters of the social system, being under the influence of another information system, with the help of this approach have been carried out. However, to describe the so-called "threshold effect" and "transients processes" - this may be insufficient, because these phenomena significantly functionally differ from the "classic" mode of the existence of a social system.

It is necessary first to define the basic notation. In theory of social dynamics systems threshold effect appears at a certain critical value in one or more parameters, whereby the system undergoes a qualitative change in a relatively short time.

Transients are processes that take place between two stable positions of the system, in our situation they appear by reaching the threshold effect.

As already noted the complexity of describing the social and political processes is in their dependence on the "freedom of the will of man". Hence we should remember that each individual is a complex system. They can generate their own decisions and actions, which are not always dependent on the general laws in force in the environment. Moreover, each individual is a psycho-physical system with multiple levels of perception and processing of personal data and the corresponding personality characteristics, which are formed by social environment surrounding him personally and unique human genetic code. There is a number of factors that are different approximations, which can be considered as random and natural.

Partly, as we have already said, it is possible to solve by the way of providing social processes as a wiener, that is, assuming manifestations of human "free will" similarity fluctuations and modeling them as a certain stochastic force.

It is easy to guess that unlike physical systems, where the transients, for example, are defined as the dynamic response of the system to an applied external influence to it since the application of exposure to some steady-state value in the time domain. We should not be limited for the social system to the influence of other social systems or the environment. Indeed, the individual or groups of individuals are capable independently without external (non-systemic) effects to have an impact on the system. This brings it out of balance that for a physical system seems to be impossible. This is due to the fact that the individual itself is a highly complex system, which is due to some laws of psychology, it can never be completely switched to another (eg, social) system because its solutions may be formed in a sense, a system in which he on all social sign is located. The most striking manifestation of this - people with serious mental illness. Part of the time they can operate within the environment of the social system, submitting to its laws and regulations, and the other part (for example, being in the so-called "twilight state") is in complete isolation from the surrounding reality or even sharply breaking its rules and the established order.

This greatly complicates the selection or creation of the theory to describe the chain reaction in social systems. It is obvious that most of the physical models do not answer the necessary requirements for the simulation internal processes. This is partly achieved by stochastic equations, thus social and political processes are considered as Wiener. Launched earlier model of the communication field with the socio-energy approach [2-3, 5] is able to simulate the particular case of the development of the social system, the evolutionary transition from one stable state to another, but it is lack of opportunities in the simulation of high-quality short-term changes in its apparent. We will not give it full here, details can be found at its respective links above, but remember that Holyst J.A., Kacperski

K., Schweiter F. Aoffered the convenient model of public opinion on the basis of the idea of interaction between individuals, in the form of Brownian motion [1, 7].

Applying socio- energy approach and moving away from the faceless ±1 to coefficients K_s - scientific development and K_{so} - social and spiritual activity, it was useful to make some significant changes. In this process, the individuals participate, interacting through the field of communication:

$$h_k(x,t), x \in S \subset \mathbb{R}^2$$

This field takes into account the spatial distribution of the coefficients and distributes in the community, modeling the transfer of information. But you should understand that it is a social space that has physical symptoms, but in terms of development of information tools is clear that the influence of one individual on another is not indispensably to do, being physically close. Thus, this space - a multi-dimensional, "socio-physical", characterizing the possibility of one individual "reach" their communications field to the other. It means to influence on him, on his coefficients and on the ability to move. It is clear that, in addition, in fact, despite the physical space coordinates, it will be the social and coordinates (describing the social situation of the individual and taking into account the informative penetration of the society).

Spatial- temporal variations in the field of communication are taken into account by the equation:

$$\frac{\partial}{\partial t} h_k(x,t) = \sum_{i=1}^{N} f(k_i, k_n)\delta(x - x_i) + D_h \Delta h_k(x,t) \tag{1}$$

$\delta(x - x_i)$- Dirac function -δ

$f(k_i, k_n)$- function that determines the power of an individual influence on another exact individual, depends of their coefficients

N – amount of individuals

D_h – diffusion coefficient characterizing the propagation of the communication field.

Every person who is at the point x_i, continuously contribute to the field $h_k(x, t)$ in accordance with the terms of their coefficients (which also determine the influence and power of the individual to the surrounding individuals, and the radius of influence).

Field $h_k(x, t)$ carries an impact on the individual I as follows. Being at the point x_i, individual falls under the influence of the communication field of another individual (or several). Depending on its difference from its coefficients and ratios of individuals acting on it, it can react in the following ways:

1. Changes the value of its coefficients under the influence of other individuals,

2. Moves toward the area where the rate difference is relatively minimal at the moment.

Thus, with the help of this model was carried out computer simulations of the influence of the information of one social system on another, which revealed a pattern of such processes as reflexivity, as well as the presence of characteristic peaks (bifurcations) [3,5]. A properties data generation peak indicate the presence of such processes in threshold effects, but because of the wide use of stochastic equations and, accordingly, the element of chance and severe fluctuations in the output, makes this model scope limited.

Indeed, as mentioned above, a small change in threshold effects of any parameter may lead to a qualitative change in the whole system. However, when we use this model, the inaccuracy of determining and changing these parameters is too high. This makes its use possible in predicting in some cases the development of the system without drastic changes, in the information wars, when there is a distinct vector of parameters.

Accordingly, for a more precise description of threshold effects it is necessary to have a mathematical theory, which has already been tested for them with the changes that take into account the specificity of human behavior (both individual and mass).

Branched chain reaction

As noted physicists, chemists know very well about chain reactions, prediction of them and, managing them. They created several models and theories for a number of phenomena. Significant interest to our study is the so-called "branched chain reaction".

In chemistry, a chain reaction, in which, besides the reactions of initiation, propagation terminate chain reactions of chain branching. In one branching reaction active site generates the appearance of two or more active centers (atoms, radicals). Examples of branched chain reactions are hydrogen combustion, oxidation of carbon monoxide, the combustion fumes phosphorus decay NSl3 [8].

Branched chain reactions have a number of significant differences from the non-branched chain. The mechanism of these reactions has been opened N.S. Semenov and Hinshelwood (as well as their team) in the years 1925-28. By studying the conditions of ignition of vapors of phosphorus, N. Semenov, Y.B. Chariton and Z.F. Jacks found that the transition from no response to a flash vapor occurs at a strictly definite pressure of oxygen, which depends on the diameter of the vessel. In 1928, Semenov proposed mechanism of branched chain process involving oxygen atoms [9].

Radical chain reaction occurs if the conversion of the reactants takes place through the active intermediate particles - atoms and radicals, and reactions involving them form a vicious cycle of transformations and the continuation of the chain is faster than an open. It is a branched chain reaction, if it takes such a stage in which one atom or radical generates the formation of several atoms and radicals. As a result, a favorable condition for the reaction increases the concentration of active centers and, accordingly, increases the reaction rate. This often results in a fire or explosion. If the branching takes place by the interaction of an atom (radical) to the molecule, by virtue of the conservation of an odd number of electrons in radical reactions in a system of a single appear 3 having an unpaired electron (in general $2n + 1$).

An important feature of the kinetic branched chain reactions, which distinguishes them from other reactions, including chain is critical or marginal phenomenon. For systems that turn on the mechanism of branched chain reactions, the presence of conditions where the reaction occurs rapidly, often with a bang is characteristic.

The transition from one mode to another takes place with a slight change in the conditions of critical values . For example, a pair of phosphorus at a fixed ratio [P4]: [O2] react with oxygen in the pressure p, which lies between two limit pressures p1 and $p2$: $p1 < p < p2$. When $p < p1$ and $p > p2$ pairs phosphorus react with oxygen. Field of ignition depends on the composition of the mixture so that the critical condition for ignition by the equation (C1 and C2 are constants). [8]

Chain explosion - very fast (explosive) flowing branched chain reaction in a non-stationary mode of its occurrence, when chain branching prevails over the cliff.

Critical phenomena in branched chain reactions - when branched chain reaction occurs under conditions in which the rate of branching and termination similar, in this mode, there is a very strong (critical) dependence of reaction rate on the conditions of its implementation, such as temperature, pressure, size reaction vessel, the concentration of reagents, the number of chemically active do pant substance - of a chain reaction inhibitor. It is enough of small change of one of the options to switch from fast (explosive) reaction to its practical stop and vice versa. These boundary conditions are said to be critical [8].

The area of branched chain reaction depends on the temperature. When a mixture of fixed composition $p = const$. There is a temperature above which there is rapid reaction and below which the reaction does not occur. In the coordinates pT ignition region for the branched chain reaction has a view of the Cape Peninsula (T_{min}), so that at $T < T_{min}$ reaction does not occur under any pressure in the system. Marginal phenomenon explains the general theory of branched chain reactions.

In a straight chain reaction, the concentration of active sites depends only on the velocities v_i initiation and termination ($v_t = gn$, where g - specific rate of chain termination in the presence of an inhibitor InH, $g = k_{InH}[InH]$], in the quasi-mode $n = v_i / g$).

In the branched chain reaction situation is fundamentally different. Acts of branching allow the progressive increase in the concentration of active centers in time. In the situation of breakage and branching chains by reacting 1th order specific velocities and g f, respectively, the rate of change of concentration of active centers n is described by the equation [8]:

$$dn/dt = v_i - (g - f)n \qquad (2)$$

There are two fundamentally different modes of reaction. Quasi-steady state, when g > f, breakage predominates over branching, then $n = v_i / (g-f) = const$, since $t > (g-f)^{-1}$ and unsteady when $f > g$, t. branch is dominant. In this case, the concentration of active centers continuously increases over time, and if we do not take into accounts the consumption of reagents and the time variation of the v_i, g and f, then

$$n = v_i (f-g)^{-1} (e^{(f-g)t} - 1) \qquad (2`)$$

A critical condition for the transition from one state to another is the equality $f = g$. Thus, the chain reaction, branching occurs as a self-accelerating process only when the active sites quickly come to the acts of branching than in the Acts of the cliff. [8]

Here it becomes clear why branched chain reaction selected as an analog flow limiting phenomena in the social and political processes. Indeed the generation of active sites in a chemical reaction is remarkably similar to the process of generating centers of activity in the riots, revolutions, even in the information war of protracted type. But also there are many differences. Firstly, they apply to the model parameters. The individuals and groups of individuals need to be described wider than the free radicals and molecules. Their capabilities are broader exposure scenarios and interaction.

So, we will make a small model of the distribution of information "virus - ideas" in the social and physical space. We assume that this information virus is active, efficient and is able to hit the cognitive individual installation for the next subsequent infection quickly.

Then:

N – the number of the "virus" carriers

G – the rate of informational circuit termination

F – branching rate of information flow in environment

V_t – the rate of individuals infection contamination

The external form of the equation does not change:

$$\frac{dN}{dt} = V_t - (G - F)N \qquad (3)$$

However, its parameters change significantly.

$$G = f\left(K_c, K_{н}, I_p, S_p, X_{ext}\right)$$

$$F = f\left({K^N}_c, {K^N}_{н}, I_p, S_p, X_{ext}\right)$$

$K_c, K_{н}$ – factors of social activity and scientific potential, respectively, for uninfected individuals or groups of individuals

${K^N}_c$, ${K^N}_{н}$ – factors of social activity and scientific potential, respectively, for infected individuals or groups of individuals (active sites)

I_p – Information permeability of the social system

S_p – Information permeability of this social system

X_{ext} – function that defines an information virus and related external influence on the social system (it can almost not be).

Thus, it is important to note that unlike chemistry information virus can theoretically be transmitted with one center unlimited number of other individuals. In practice, of course, this does not happen, because the amount of people, which are known by the majority of individuals, is very limited, so it is possible to use the average parameters.

For example, if the branch Ʊ = 2, it looks like **Fig. 1**.

It is clear that this is a simplified model. To reduce the work of the information war facilities to the "infected" or "not infected" certain "virus" would be too easy. However it is known that the basic human emotions spread similar scheme, for example, epidemiological spread panic in the crowd [10-11].

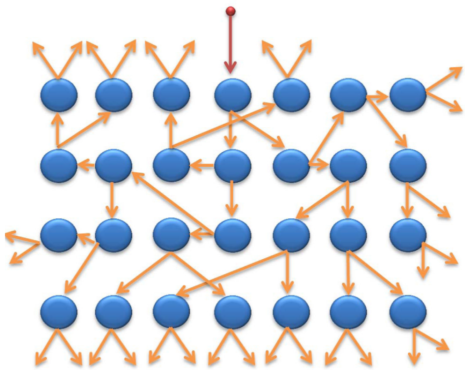

Fig. 1. Branched chain reaction branching parameter = 2

For further work with the equation (3) that define several of its parameters. First of all, needs to define the mechanism of threshold effect and its differences from its chemical equivalent. Initiation of branched chain reactions occur, for example due to the limiting pressure p1 <p <p2. There is also an analogue of the pressure in the social environment:

P_{so} – social pressure a rising from the difference of the coefficients and social energy between individuals or sub-systems of individuals within their communication fields.

The pressure can be easily determined through the energy:

$$P_{so} = \frac{2}{3} n < E_{in} > \quad (4)$$

Were

n – the number of individuals

$E_{in} = \Psi E_{total}$ – interaction energy, that energy that an individual or sub-system can be directed to the interaction with other individuals or subsystems. Obviously, it cannot be greater than the total social energy of the individual.

Ψ- energy transfer coefficient

$$\Psi^i = K_s^i K_{so}^i \quad (5)$$

Thus, for each individual is true:

$$E^i{}_{in} = \Psi^i E^i{}_{total} \quad (6)$$

Since the energy dissipation in the social-physical space is not, you can consider this system as Hamiltonian:

$$E^i{}_{in} = \Psi^i H^i \quad (7)$$

H^i – Hamiltonian of the individual or individual's subsystem.

Then we can write the first canonical Hamiltonian equation:

$$\frac{d}{dt} P^{ij}{}_{so} = \Psi^i E^i{}_{total} - \Psi^j E^j{}_{total} = \Delta(\Psi^{ij} E^{ij}{}_{total}) \quad (8)$$

Hence

$$\frac{d}{dt} P^{ij}{}_{so} = \Delta E^{ij}{}_{in} \quad (9)$$

This leads us to

$$\frac{d}{dt} P^{ij}{}_{so} = \Delta(\Psi^{ij} H^{ij}) \quad (10)$$

That is the fundamental equation to describe the social pressures of society's interactions between individuals and subsystems individuals.

Conclusion

Thus, in this paper we have proposed a mathematical model by which the author intends to further develop an approach to model and study the threshold effects. Using proven approaches of scientific disciplines in the humanities applications seems promising. Indeed, the generality of the laws of nature extends to its integral part-human, albeit often we forget about it.

Simulation of a number of social and political processes through the mechanism of generation and flow of branched chain reactions can be an effective way for forecasting such processes.

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