International Journal of 3D Printing Technologies and Dijital Industry
Uluslararası 3B Yazıcı Teknolojileri ve Dijital Endüstri Dergisi

SYSTEM-DYNAMIC MODELS OF DESTRUCTIVE INFORMATIONAL INFLUENCE IN SOCIAL NETWORKING SERVICES

Kateryna MOLODETSKA[a]*, Yuriy TYMONIN[b]

[a]Zhytomyr National Agroecological University, Educational and Scientific Center of Information Technologies, UKRAINE
[b]Zhytomyr National Agroecological University, Faculty of Accounting and Finance, Department of Computer Technologies and Systems Modeling, UKRAINE

* *Correponding Author: kmolodetska@gmail.com*

(Received: 15.04.2019**; Revised:** 16.05.2019**; Accepted:** 15.07.2019**)**

ABSTRACT

In modern conditions, social networking services have become one of the most popular mass media. Due to a large number of additional functions, besides providing social communication, services are used to influence social and political processes. As a result of the spread of content of destructive matter from anywhere in the world by intruders, threats to the state's information security are being delivered. Currently there are no valid and effective methods to opposing the information impact on virtual community actors in social networking services. Therefore, the scientific and applied task of improving and further developing models of destructive informational influence in social networking services, which is going to allow to oppose threats to the state's information security timely, is especially urgent. In the article the model of destructive informational influence in social networking services is offered on the basis of the system dynamics method by J. Forrester. The conceptual basis of the system-dynamic model, which includes content, traffic content, and dynamics' index number of content in time, is formulated. The approaches to constructing loops of linear and nonlinear feedback of actors' interaction in the virtual communities of social networking services are presented. Nonlinear analytical models of system dynamics of informational influence in social Internet services as partial cases of second-order nonlinear differential equations are developed. The approaches to conducting a controlled transition of the information space of social networking services through parametric control using a system-dynamic model of destructive informational influence are offered. The considered models can be used for constructing complex models of system dynamics of social communication in virtual communities in the conditions of conducting information confrontation in order to ensure state's information security in social networking services.

Keywords: social networking services, state's information security, informational influence, content, actors.

1. INTRODUCTION

Social Networking Services (SNS) are an on-line platform that is used for social interaction of users among themselves on the Internet. At the same time users of SNS are called actors, they have their own profile with personal information, form their own social circles and carry out social communication [1], [2]. At present, SNS form a great part of the traditional media market. This situation is related to the use of SNS for the creation of virtual communities by actors with the common interests. SNS is an effective tool of job for service providers, marketers, sociologists, managers, and many other specialists [3]. However, one of the most important areas of the research is the study of the SNS's role in the processes of state-building, making the important social and political decisions, and so on. As a result of information operations in SNS in real life, displays of social tension, manipulation of citizens' public opinion, interethnic and inter-confessional conflicts, etc. can be spread [4]-[6]. For example, there are known facts

of effective use by the Russian Federation of information counter centers for conducting a hybrid war against Ukraine. So, the centers have been used to discredit the political leadership and command of the Armed Forces of Ukraine, to form the idea of spreading racism in Ukraine and cultural intolerance, the formation of anti-Ukrainian mood in the population of temporarily occupied territories, etc. [4], [7], [8]. In this way, SNS is an instrument for influencing the information security of a person, society and state [6]. As a result, there is an objective contradiction between the need to ensure sustainable development and the security of the information space while using SNS by actors on the one hand, and the lack of effective approaches to ensuring the state's information security in SNS under conditions of information confrontation.

2. LITERATURE REVIEW

2.1. Features of conducting information confrontation in SNS

At the present stage of the IT industry development, SNS has become a tool for conducting an information confrontation, which is primarily due to the peculiarities of their functioning. The principals' achievements of the information influence of the set goals are simplified by the unlimited access of SNS to a wide range of actors [4], [9]. The purpose of conducting information confrontation in SNS is to obtain information superiority over the opponent by informational influence on actors to disrupt their moral and psychological stability, while simultaneously protecting against similar influence from the enemy. Professor Hryshchuk R. V. in [4] notes that forms of information confrontation run are information share, information event, information operation and information campaign. The considered forms of information confrontation form a hierarchy of information actions, at the lower level of which is an information share. Information campaign in SNS is a set of agreed and interrelated goals, objectives, objects and time events of informational influence on actors of virtual communities. The purpose of the information action can be [10]: the influence on the psychological and emotional state of the SNS actors; influence on freedom of choice; calls for separatism, overthrow of the constitutional order, violation of territorial integrity, etc.; discrediting public authorities; support, maintenance or activation of criminal or terrorist activities, and others. In this case, the objects of influence of information actions are certain citizens, society or state.

Information shares are implemented in the SNS information space by promotion of multimedia content, which contains destructive informational influence on actors in explicit or implicit form. Upfront detection of such information influences and effective counteraction to them is inextricably linked with the dynamics' study of such content in the SNS information space [11].

2.2. System dynamics in the study of informational influences in SNS

As a result of the analysis of previous studies' results [12]-[15], it has been established that simulation, agent, and mathematical modeling are among the most common methods for investigating the interaction of actors in SNS. Also, algebraic, stochastic models, game theory methods, the mathematical apparatus of the Markov's chains, etc. are used. The disadvantages of the considered approaches to studying the processes of promoting the destructive informational influence in SNS are the need for a large sample of statistical data, the complexity of parametric model identification under the influence of latent threats, exponential growth of computational complexity for large virtual communities of actors, low scalability, etc.

A special place in the study of the actors' interaction in SNS and the spread of destructive informational influence belongs to the systemic dynamics of J. Forrester [16], [17]. To the basis of the system dynamics, the following principles are set [17], [18]: the definition of the system basis variables and elements; development of a circuit of positive (intensifying) and negative (stabilizing) feedback loops in the form of graphs; formalization of the analytical model of the object's system dynamics for a graph in the form of nonlinear differential equations' system of the second order. Thus, the interaction of actors in SNS is formalized because of the causal structure of the virtual community and considers the feedback between the individual actors. Feedback is formed as a result of the actors' reaction in SNS to destructive content of the directed matter and leads to the further dissemination of this content in the information space. Thus, the significant advantage of using the method of system dynamics to ensure the state information security in SNS is the possibility of studying the aspects of system behavior in time, considering the links between actors of virtual communities.

However, the implementation of the principles of system dynamics above to ensure information security of the state in SNS is associated with several uncertainties. Firstly, there is a large number of initial variables and elements - levels, flows, valves, information channels, delay lines and auxiliary lines. This complicates the process of modeling the interaction of actors in SNS. J. Gharajedaghi in the paper [19] suggests using four basic elements - level, flow, converter and connector. The listed elements allow to fix the status of variables, feedback loops, mutual influence and nonlinearity, they are enough to develop a model of the dynamics of information influence in SNS. Secondly, the complexity of the detection procedure is the feedback loop interaction scheme. Such scheme establishes the interdependence of elements, through which the systemic nonlinearity in general is formed [20]. On the other hand, in the paper [21] a scheme of interaction of feedback loops is given in the formation of equations of system dynamics in the basis of phase variables.

However, it remains unresolved to determine the factors that are considered in the system-dynamic model (SDM). As a result of this uncertainty, the dimension of the variables' basis of the system model increases significantly. Consequently, due to the complexity of processes' nature of social communication in SNS, the study of such phenomena requires the improvement and further development of SDM of destructive informational influence in SNS, which will allow to formalize and timely detect the processes of content dissemination of targeted matter in SNS and to oppose the threats to the information security of the state. This, in turn, further updates the chosen direction of scientific research.

The purpose of the article is the formalization of the SDM to content distribution of destructive matter by actors in SNS while conducting information operations against the state's information security.
To achieve this goal, the following partial tasks need to be solved:
1) to define the conceptual basis of SDM for the content distribution of destructive matter in SNS and to determine the relation between its variables;
2) to form schemes of construction and interaction of loops of linear and nonlinear feedback between actors in SNS;
3) determine the order of formation of nonlinear analytical models of system dynamics;
4) to establish features of SDM distribution of content destructive matter and approaches to parametric management of the equilibrium model.

3. MATERIAL AND METHOD

3.1. Conceptual basis of SDM destructive informational influence

Conceptual basis of SDM distribution of content destructive matter in SNS is conceptual, which appears in minimum basis of primary variables and elements. Conceptual basis of SDM of destructive informational influence consists of independent and dependent dimensions. The independent dimensions of the model include:
1) fundamental variables of the information space of SNS l and time t;
2) primary independent phase variables that are considered as dimensionless quantities:
a) the number of content publications $Y(l,t)$ in SNS, that forms a destructive informational influence;
b) an integral indicator $\Phi(l,t)$ of the promotion of destructive content $Y(l,t)$ in the information space l of SNS and time t.
Independent conceptual basis of SDM of destructive informational influence in SNS is a minimal set of variables $\{Y,\Phi,l,t\}$ enough for its formalization.

Dependent dimensions of SDM of destructive informational influence in SNS will be introduced using the fundamental variables by differentiating and integrating independent phase variables.
Limitation. In the article, we consider the description of SDM of destructive informational influence in time, and its description in the SNS information space is determined analogously.
Dependent Phase Variables of SDM and their connections with Independent Phase Variables:
a) the flow of destructive content in SNS

$$y(t)=Y'(t),\ Y(t)=\int y(t)dt, \quad (1)$$

b) differential indicator of the destructive content promotion in SNS $\varphi(t)$

$$\varphi(t) = \Phi'(t),\ \Phi(t) = \int \varphi(t)dt\ . \tag{2}$$

Dependent quantities include the following elements – an integrator and a differentiator, then the working conceptual basis of SDM description in time represents a set of variables $\{X, x, \Phi, \varphi, t\}$.

3.2. The ratio of variables in a working conceptual basis and operations over them

In the basis of relations between phase variables, we put the principle of direct proportionality, according to which the relations between the values of two interrelated quantities remains unchanged. Then we define four types of relations between variables:

a) the number of publications of destructive content in SNS is directly proportional to the traffic indicator in the information space

$$Y(t) = b_0\varphi(t), \tag{3}$$

where b_0 – is the coefficient of capacity of the SNS information space, determined by the maximum amount of content publications during the information share;

b) the dimension of destructive content's promotion in the information space of SNS is directly proportional to its flow

$$\varphi(t) = b_1 y(t),\ \Phi(t) = b_1 Y(t), \tag{4}$$

where b_1 – is the coefficient of the critical thinking level of virtual communities' actors in SNS and characterizes the reasonable rejection of the distributed narrative by the target audience;

c) the integral indicator of the motion of destructive content in the information space of SNS is directly proportional to the flow of such content

$$\Phi(t) = b_2 y(t), \tag{5}$$

where b_2 – is the coefficient of actors' sensitivity to the content of destructive matter in SNS, the ability to his absolute acceptance on faith as reliable information.

In turn, the proportionality coefficients b_0, b_1, b_2 – are the parameters that are determined by the peculiarities of the SNS information space.

Additive algebraic adding and subtracting operations are also allowed for phase variables.

3.3. SDM construction of destructive informational influence

Using relations between phase variables and operations over them, we will make SDM growth and spreading of destructive content in SNS.

3.3.1. Model of accelerated growth of destructive content in SNS

As the basis of SDM, we consider a model of accelerated growth, which describes the increase in the number of publications of destructive content in SNS by means of the external information space. To form a model of accelerated growth we use the provisions [22]: the rate of content growth in SNS is proportional to the amount of this content with a coefficient, equal to the differential index of motion

$$y(t) = \varphi^{+}(t)Y(t)\ . \tag{6}$$

On the other hand, equation (6) can be considered as an equation of a positive feedback circuit, which connects the input of the integrator with its output.

To construct a model of accelerated growth of destructive content in the SNS information space, we will use the principle of positive feedback. In accordance with this principle, as a result of the information share, in SNS the information influence on actors is spreading further. To do this, we mark a system of accelerated equations, which reflects the functional scheme with the dedicated equations of direct transmission and positive feedback

$$\begin{cases} Y(t) = \int y(t)dt, \\ y(t) = \varphi^{+}(t)Y(t); \end{cases} \tag{7}$$

where the first equation of the system is the equation of the direct transmission based on the integrator; the second is the equation of the positive feedback circuit.

An important moment in the formation of the equation of the positive feedback circuit is that the differential indicator of the motion of destructive content in SNS $\varphi^+(t)$ in the structural representation can be considered as the transfer coefficient of the positive feedback circuit. This gives grounds for parameterizing of this variable, when in a limited time interval, the traffic indicator is considered as a parameter $\varphi^+(t) \approx \varphi^+$. In general, the model of accelerated growth (7) of the amount of destructive content in SNS is described by the differential equation of the first order

$$\frac{dY(t)}{dt} - \varphi^+ Y(t) = 0. \tag{8}$$

The classical equation of accelerated growth (8) is well-known (Poincare's, Malthus's equation) and has an analytic solution in the form of an exponential function $Y(t) = Y(0)\exp(\varphi^+ t)$. In the dynamic description, the transfer coefficient of a positive feedback circuit is considered as an exponential growth index φ^+.

The exponential function shows an unlimited increase in time in the number of publications of content of destructive matter in SNS and has a high sensitivity to changes in the traffic indicator. These properties limit the application of the accelerated growth equation as an independent model.

3.3.2. The scattering model of destructive content in the information space of SNS

The scattering models of content in the information space of SNS reflect the phenomenon of reducing the value of the content stream in proportion to its level. The model-building of scattering the destructive content in SNS, which is distributed during an information share, we are going to use the principle of negative feedback. Let's write the equation of scattering in the form of a functional scheme with distinguished direct-transfer equations and negative feedback

$$\begin{cases} Y(t) = \int y(t)dt, \\ y(t) = \varphi^-(t)Y(t); \end{cases} \tag{9}$$

where $\varphi^-(t)$ – is the coefficient of the total transmission in the negative feedback circuit.

If we construct a negative feedback using a simple scheme like a positive feedback in the second equation of system (7), then the overall effect will depend only on the difference of transmission coefficients. Therefore, for negative feedback, we need to use a more complex design than for positive feedback. Let the negative feedback circuit consist of several contours, be nonlinear and have a parametric character.

We formalize the overall negative feedback circuit as a parallel scheme from three contours in which it can add destructive content flows to SNS at the input of the integrator $y^- = y_0^- + y_1^- + y_2^-$. Then, considering the second equation of system (9), the total transmission coefficient is represented as the sum of the transmission coefficients of the three negative feedback circuits $\varphi^- = \varphi_0^- + \varphi_1^- + \varphi_2^-$. The nonlinear nature of the simple negative feedback contours can be contributed by the parametric dependence of the transmission coefficients from the phase variables. Considering the expressions (1)–(5), we represent the coefficients of the transfer of negative feedback circuits through phase variables in the form of

$$\varphi_0^-(t) = b_0 Y(t),\ \varphi_1^-(t) = b_1 y(t),\ \varphi_2^-(t) = b_2 \Phi'(t) \tag{10}$$

For the general negative feedback circuit, considering and adding transfer coefficients, we obtain the equation for the coefficient of transmission of the whole negative feedback circuit

$$\varphi^-(t) = b_2 \frac{d^2 Y(t)}{dt^2} + b_1 \frac{dY(t)}{dt} + b_0 Y(t). \tag{11}$$

The second-order linear differential equation will be considered as the general scattering model of destructive content in the information space of SNS, which describes the fading dynamics of its propagation as an oscillatory process.

3.3.3. Nonlinear SDM of destructive informational influence in SNS

Considering SDM as an aggregation of growth (7) and scattering (11) models of destructive content in SNS based on the general circuit of direct transmission, we write down the initial system of equations

$$\begin{cases} Y(t)=\int y(t)dt, \\ Y'(t)=\left(\varphi^{+}(t)-\varphi^{-}(t)\right)Y(t), \\ \varphi^{-}(t)=b_2Y''(t)+b_1Y'(t)+b_0Y(t). \end{cases} \quad (12)$$

By combining expressions (12), we get an expression for the SDM as a motion equation of the content in the SNS information space in the form of a nonlinear differential equation of the second order [22], [23]

$$b_2Y(t)\frac{d^2Y(t)}{dt^2}+\left(1+b_1Y(t)\right)\frac{dY(t)}{dt}+\left[b_0Y(t)-\varphi^{+}(t)\right]Y(t)=0. \quad (13)$$

While combining expressions (12), the scattering indexes from the third system expression (12) are multiplied by the magnitude $Y(t)$ of the second equation of system (12), which leads to the nonlinearity of equation (13). From the general equation (13) we get partial cases, of which we note the following:

1) by $b_2=0$ we get a generalized logistic equation of the first order

$$\left(1+b_1Y(t)\right)\frac{dY(t)}{dt}+\left[b_0Y(t)-\varphi^{+}(t)\right]Y(t)=0 \quad (14)$$

The nonlinear equation (14) corresponds to a circuit with a positive feedback loop and two nonlinear negative feedback circuits like $\varphi_0^{-}(t)=b_0Y(t)$ i $\varphi_1^{-}(t)=b_1y(t)$;

2) by $b_2=0$ and $b_1=0$ we get the logistic equation of Ferghüst

$$\frac{dY(t)}{dt}+\left[b_0Y(t)-\varphi^{+}(t)\right]Y(t)=0. \quad (15)$$

The nonlinear equation (15) corresponds to a scheme with a positive feedback circuit and a nonlinear negative feedback circuit like $\varphi_0^{-}(t)=b_0Y(t)$.

The heuristic approach of the Ferghüst's logistic equation can be considered as the first simplest SDM containing the positive and negative feedback circuits and described by the nonlinear differential equation of the first order. The solution of the equation (15) has the form of logistic function

$$Y(t)=A\frac{c\mathrm{e}^{\varphi^{+}t}}{1+c\mathrm{e}^{\varphi^{+}t}}, \quad (16)$$

where $A=\dfrac{\varphi^{+}}{b_0}$ – is the asymptotic threshold of the logistic function.

The logistic function contains the equilibrium area, where the nonlinear negative feedback, boosted by parametric dependence, compensates the growth due to the linear positive feedback.

The equilibrium area, which is an important characteristic of SDM [18], [24], is often analyzed as the goal of managing the processes of actors' social communication in SNS. Therefore, the increased focus is given to this characteristic.

4. EXPERIMENTAL RESULTS

Let's explore examples of the use of offered SDM destructive informational influence in SNS. Particularly relevant is the task of identifying the SDM equilibrium area as a fixed level of publications' content of destructive matter as a result of information share's realization in SNS. To do this, we will use SDM in the form (13), which takes into account the increased demand for such content and its dissipation in the information space of SNS, which affects the number of publications in virtual communities. Since SDM (13) contains, as a separate case, the logistic equation (15), it can be shown that the threshold of logistic function (15) is a conventional "threshold" for a general SDM (13). It means that SDM (13) contains the equilibrium area defined by the threshold of the logistic function, to which asymptotically the number value of destructive content's publications in SNS is sent over large time intervals

$Y(t\to\infty)\to A(\varphi^{+},b_0)$.

Let's perform simulation of change of logistic threshold value $A(\varphi^+, b_0)$ for a model (13) at such values of parameters as $\varphi^+ = 0{,}5$; $b_2 = 0{,}2$; $b_1 = 0{,}001$. Figure 1 shows the curves that reflect the movement of the logistic threshold $A(\varphi^+, b_0)$ when changing the parameter b_0.

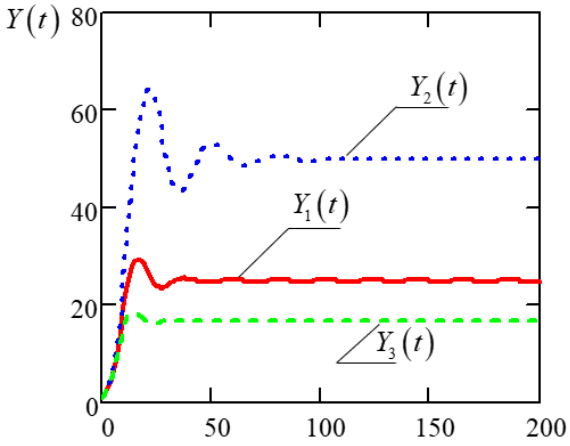

Figure 1. The change of the SDM logistic threshold: $Y_1(t)$ when $b_0 = 0{,}2$, $A = 0{,}5 / 0{,}2 = 25$; $Y_2(t)$ when $b_0 = 0{,}1$, $A = 0{,}5 / 0{,}1 = 50$; $Y_3(t)$ when $b_0 = 0{,}3$, $A = 0{,}5 / 0{,}3 \approx 17$.

Consequently, the fixed amount of publications of destructive content as a result of an information share is determined by the capacity value of the SNS information space, which is the end value of content publications' volume. The impulse of the artificial demand of virtual communities' actors for the content of destructive matter during the conduct of information actions is achieved by increasing the capacity of the SNS information space. The obtained result is due to the psychological effects that arise during social communication in the virtual space. In particular, a spiral of silence, when actors hide their public opinion, if it does not coincide with the opinion of the majority. Also, the gregarious instinct is used by the opposing side during the interaction of actors in virtual communities, according to which more attention is paid to content publications with a large number of comments, "likes", "reposts," participants.
Figure 2 shows the curves reflecting the stability of the SDM logistic threshold relative to the coefficients b_2 and b_1. Line charts $Y(t)$ of the number of publications of destructive content in SNS are constructed according to the equations (13), (14) and (15) for the parameter values $\varphi^+ = 0{,}5$; $b_2 = 0{,}2$; $b_1 = 0{,}001$; $b_0 = 0{,}01$ and the logistic threshold $A = 0{,}5 / 0{,}1 = 50$.

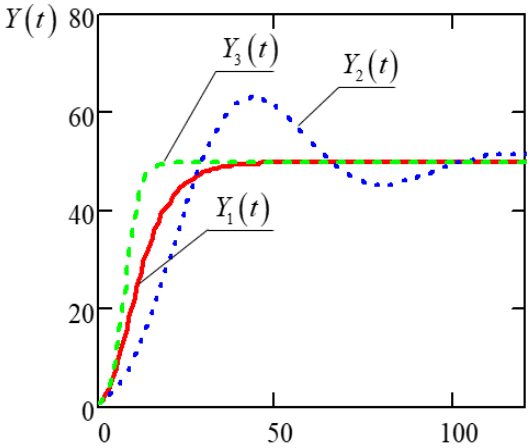

Figure 2. Stability of the logistic threshold: $Y_1(t)$ for SDM (14) with $b_2 = 0$, $b_1 = 0{,}001$, $b_0 = 0{,}1$; $Y_2(t)$; for SDM (13) $b_2 = 0{,}2$, $b_1 = 0{,}001$, $b_0 = 0{,}1$; $Y_3(t)$; for SDM (15) with $b_2 = 0$, $b_1 = 0$, $b_0 = 0{,}1$.

Analysis of Figure 2 shows that the transition of a function to a set level of the logistic threshold for selected models (13) – (15) occurs at different time intervals. Thus, the SDM of destructive informational influence in SNS (13) can be considered as a universal module for constructing complex system dynamic models of social communication in the virtual space in conditions of information confrontation's maintenance. In turn, the interaction of actors in SNS is formalized as a set of SDM modules. This approach will consider the peculiarities of informational shares' organizing and maintenance by the opposing side. The SDM equilibrium area is of interest to ensure the state's information security in SNS as the goal state of the virtual community. Also, the model parameters φ^+, b_0, b_1, b_2 can be used for parametric control of the content distribution of destructive matter in order to oppose threats to the state's information security in SNS.

5. CONCLUSION

The model of destructive informational influence on actors in social Internet services based on J. Forrester's system dynamic method is offered. The minimal conceptual basis of SDM of destructive informational influence in the form of a phase variables' set is defined, and it includes content, traffic content and indicators of content distribution in time. The schemes of construction and interaction of linear and nonlinear feedback loops of actors' interaction in virtual communities based on the general chain of the content's direct transmission in the information space of SNS are formed. The case of using one contour of linear positive feedback and three contours of a nonlinear negative feedback interaction of actors in the virtual communities of SNS is analyzed.

The order of formation of nonlinear analytical models of system dynamics in the form of a nonlinear differential equation of the second order is presented on the basis of the detailed analysis of the parametric dependence of the negative feedback of the actors' interaction. The approaches to parametric control of the status of the SNS information space with the use of SDM are presented. Consequently, SDM of destructive content in SNS can be used as a universal module for constructing complex models of system dynamics of social communication in virtual communities.

REFERENCES

1. Boyd, D. M., Ellison, N. B. "Social network sites: Definition, history, and scholarship", Journal of computer-mediated Communication, 13(1), Pages 210-230, 2007.

2. Park, N., Kee, K. F., Valenzuela, S. "Being immersed in social networking environment: Facebook groups, uses and gratifications, and social outcomes", CyberPsychology & Behavior, 12(6), Pages 729-733, 2009.

3. Liang, T. P., Ho, Y. T., Li, Y. W., Turban, E. "What drives social commerce: The role of social support and relationship quality", International Journal of Electronic Commerce, 16(2), Pages 69-90, 2011.

4. Hryshchuk R. V., Danyk Yu. H., "Osnovy kiberbezpeky" [Fundamentals of cybernetic security] [book in Ukrainian], 636 pages, ZhNAEU, Zhytomyr, 2016.

5. Yevseiev S., Ostapov S., Rzaiev Kh., Nikolaienko V., " Otsinka obminu danymy v hlobalnykh obchysliuvalnykh merezhakh na osnovi kompleksnoho pokaznyka yakosti obsluhovuvannia merezhi" [Estimation of data exchange in global computer networks on the basis of an integrated indicator of network service quality] [article in Ukrainian], Radio Electronics, Computer Science, Control, 1(40), Pages 115–128, 2017.

6. Hryshchuk R., Molodetska-Hrynhchuk K., "Methodological Foundation of State's Information Security in Social Networking Services in Conditions of Hybrid War," Information & Security: An International Journal, Vol. 41, Pages 55-73, 2018.

7. Badawy, A., Ferrara, E., Lerman, K. “Analyzing the digital traces of political manipulation: The 2016 russian interference twitter campaign”, 2018 IEEE/ACM International Conference on Advances in Social Networks Analysis and Mining (ASONAM), Pages 258-265, 2018.

8. Giles, K. “The Next Phase of Russian Information Warfare”, NATO Strategic Communications Centre of Excellence, Vol. 20, 16 Pages, 2016.

9. Hrabar, I., Hryshchuk, R., Molodetska, K. “Bezpekova synerhetyka: kibernetychnyi ta informatsiinyi aspekty” [Security synergy: cybernetic and informational aspects] [book in Ukrainian], Eds. R. Hryshchuk, ZhNAEU, Zhytomyr, 280 pages, 2019.

10. Molodetska, K. “Uzahalnena klasyfikatsiia zahroz informatsiinii bezpetsi derzhavy v sotsialnykh internet-servisakh” [Generalized classification of threats to the state's information security in social networking services] [article in Ukrainian], Information Protection, Iss. 23, Pages 75-87, 2016.

11. Molodetska-Hrynchuk, K. “Model systemy pidtrymky pryiniattia rishen dlia vyiavlennia oznak zahroz informatsiinii bezpetsi derzhavy u sotsialnykh internet-servisakh ta otsiniuvannia yikh rivnia” [Model of Decision Support System for Detection the Threats Signs to Information State Security in Social Networking Services and Assessment of Their Level] [article in Ukrainian], Information Security, Vol. 23, No. 2, Pages 136-144, 2017.

12. Hajian, B., White, T. “Modelling influence in a social network: Metrics and evaluation”, 2011 IEEE Third International Conference on Privacy, Security, Risk and Trust and 2011 IEEE Third International Conference on Social Computing, IEEE, Pages 497-500, 2011.

13. Rashidi, T. H., Abbasi, A., Maghrebi, M., Hasan, S., Waller, T. S. “Exploring the capacity of social media data for modelling travel behaviour: Opportunities and challenges”, Transportation Research Part C: Emerging Technologies, 75, Pages 197-211, 2017.

14. Bello-Orgaz, G., Jung, J. J., Camacho, D. “Social big data: Recent achievements and new challenges”, Information Fusion, 28, Pages 45-59, 2016.

15. Molodetska-Hrynchuk, K. “Adaptatsiia metodiv teorii khaosu dlia zabezpechennia informatsiinoi bezpeky derzhavy u sotsialnykh internet-servisakh” [Adaptation of Chaos Theory Methods to Provide State Information Security in Social networking Services] [article in Ukrainian], *Bulletin of the Zhytomyr National Agroecological University*, No. 2 (61), t. 1, P. 180-187. 2017

16. Forrester, J. W. “System dynamics – the next fifty years”, System Dynamics Review: The Journal of the System Dynamics Society, 23(2-3), Pages 359-370, 2007.

17. Forrester, J. W. “System dynamics: the foundation under systems thinking”, Sloan School of Management. Massachusetts Institute of Technology, 1999.

18. Forrester, J. W. “Industrial dynamics”, Journal of the Operational Research Society, 48(10), Pages 1037-1041, 1997.

19. Gharajedaghi, J. “Systems thinking: Managing chaos and complexity: A platform for designing business architecture”, Elsevier, 350 Pages, 2011.

20. Gharajedaghi, J. “Systems thinking: a case for second-order-learning”, The Learning Organization, 14(6), Pages 473-479, 2007.

21. Mahov, S. “Mathematical simulation of world dynamics and sustainable development by the example of Forrester's model” [Matematicheskoe modelirovanie mirovoj dinamiki ustojchivogo

razvitija na primere modeli Forrestera] [article in Russian], http://www.keldysh.ru/papers/2005/prep06/prep2005_06.html, March 19, 2019.

22. Brodsky, Yu., Grabar, I., Timonin Y. “Universalna model systemy. Metodolohichnyi aspekt” [Universal system model. Methodological aspect] [article in Ukrainian], Bulletin of the Zhytomyr National Agroecological University, 1, Pages 202-209, 2009.

23. Brodsky, Yu., Timonin, Yu., Timonin, A. “Uchet differencial'nyh poter' v nelinejnoj modeli jekonomicheskoj sistemy” [Accounting for differential losses in the nonlinear model of the economic system] [article in Russian], Business-Inform, 3, Pages 45-47, 2012.

24. Bayer, S. “Business dynamics: systems thinking and modeling for a complex world”, Interfaces, Vol. 34, No. 4, Pages 324-326, 2004.