Modelling Of Conflict Interaction of Virtual Communities in Social Networking Services on an Example of Anti-Vaccination Movement

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Abstract. In present-day circumstances, social networking services have turned into an effective tool for influencing social and political state processes. As a result of a systematic carrying out of information operations in social networking services, various social movements, which are supported by virtual communities of actors, are appearing. An example of such movements is the negation of effectiveness, safety and legitimacy of vaccination, in particular, mass vaccination. The dissemination and support of the mentioned narrative can threaten not only the informational but also the national security of the state itself. In order to increase the effectiveness of the research on the information confrontation between vaccine proponents and opponents in social networking services, a model of conflict interaction among virtual communities has been proposed. The model includes three layers: the dynamics of the number of two conflicting virtual communities, the growth of the resources of the information space of social networking services connected with the changes in the number of actors in the community, and the dynamics of the consumption of the resources for information confrontation. The suggested approach allows to take into consideration several aspects of the conflicting interaction of virtual communities and also provides a connection between the components of the model using the boundary meaning of the first layer of the model. The simulation results can be used for developing practical recommendations for counteracting the state's information security threats existing in social networking services.

Keywords: social networking service, virtual community, actor, information security, information confrontation, conflict interaction, vaccination.

1 Introduction

At the present stage of information society development, social networking services (SNS) have turned into the main source of communication for Internet users. Currently, SNS such as Facebook, Twitter, Vkontakte, etc. have become the cutting edge means of organizing communication space and the embodiment of social communication itself [1-6]. At the same time, SNSs are being used to establish and structure new social entities, the formation of civil society, for instance. This demonstrates the significant impact of such services on state-making, political and social processes in the real life of the country and its citizens. When used for conducting information operations by the leading countries of the world, SNS become an effective tool for conducting information confrontation [7-10]. One of the embodiments of information confrontation is the conflictual interaction of actors of virtual communities. It is characterized by the presence of opposing goals of the functioning of such communities in the information space of SNS [11-14].

An example of the usage of SNS for conducting information confrontation between the Russian Federation and the United States is the spread of disinformation containing a strategic anti-vaccination narrative. The research [15], which aim was to evaluate 2 million Twitter posts in 2014-2017, showed that Russian trolls were more likely to write about vaccination than other SNS actors. Russian bots have been found to use anti-vaccine narratives as a problem issue to strengthen social discontent, undermine confidence in health care institutions and spread fear and split US citizens.

The consequence of such systematic information operations in the SNS is the spread of the public movement that denies the effectiveness, safety, and legitimacy of vaccination, in particular, the mass one. The sceptical attitude towards vaccination includes both a complete denial of vaccinations and particular vaccines, which causes a change in the timing and of immunization schedules of the recommended by medical establishments. As a result of the increased anti-vaccine movement in Ukraine and the world in general, the number of patients and fatal cases has increased significantly. On the other hand, this has led to the formation of virtual communities that are opposed to the anti-vaccine movement. The latter is aimed at counteracting the movement of anti-vaccines and are in conflict with its supporters.

A promising area of research is the study of peculiarities of information confrontation of virtual communities aiming to reduce the level of threat to the national security of the state by counteracting destructive content in SNS. Therefore, there is an objective contradiction between ensuring the sustainable development of the SNS information space in the context of globalization and the free circulation of information and lack of effective methodological tools for the investigation of the conflict interaction of virtual communities in order to ensure the information security of the state.

Analysis of recent studies and publications has shown that the solution to the problem of conflict interaction between supporters and opponents of the anti-vaccine movement is not properly investigated. Existing studies are limited by the usage of mathematical models of epidemics, in particular, SIR models [16, 17]. The essence of this model is the division of the population into three groups: susceptible to the disease, infected people and those who have recovered and are immune to the disease.

However, such models are not able to fully describe the processes of r conflict interaction of the actors in virtual communities. Thus, the necessity for modelling of the conflict interaction of actors in the virtual communities on the example of the anti-vaccine movement is the task of increasing significance on the way of ensurance of information security of the state in the SNS.

The purpose of the article is to increase the level of information security of the state in the SNS by modelling the processes of information confrontation of virtual communities of actors, which will allow to develop practical recommendations for counteracting threats in the information space of services.

2 Models and methods

2.1 Peculiarities of conflict interaction of actors of virtual communities in SNS

To identify the signs of conflict of virtual community actors in the SNS, we will determine the interests of the conflicting parties. The essence of the narrative spread by pro-vaccination virtual communities in the SNS information can be the following: a significant reduction of the risk of catching the disease due to conducting the appropriate vaccinations. According to the World Health Organization, immunization prevents from 2 to 3 million deaths each year. It is one of the most effective types of investments in health care in terms of their value [18].

The interests of the virtual communities that are adherents of the anti-vaccine movement are manifested in the SNS by spreading content with the following narratives:

denying the role of vaccination as the factor that reduces the sickness rate;

the denial of the necessity of vaccination at present. It is claimed that mass vaccination against all or most of the diseases is inappropriate, since modern treatments for the diseases, which vaccination is carried out from, are effective enough, and the frequency of these diseases themselves is pretty low.

Thus, the essence of the conflict lies in the fact that in real life, SNS actors who oppose vaccination as a result of refusing vaccinations become vulnerable to the disease and also become a threat to those who have been vaccinated. At the same time, the conflict that takes place in the SNS information space influences public opinion in real life and encourages citizens to take certain actions and creates the background for the emergence of threats to the information security and national security of the state as a whole.

Moreover, the considered conflict interaction of virtual communities can be characterised as antagonistic - features intransigence and hostility between groups of actors and manifests in conflict on an ideological basis.

2.2 Model of antagonistic conflict of virtual communities in SNS

The modelling of conflict dynamics includes the following points [19, 20]:

- conflict models are formed as modular constructions, created on the basis of a single scheme. Such constructions can be presented as a system of equations of conflict dynamics. The equations reflect the interaction of participants, the growth of winnings and losses;
- the basis of systems of equations of dynamics of the conflict is formed by differential equations, which reflect the conflict interaction. The system of equations of the dynamics of conflict also includes the equations of growth of the results of warfare - winning and losses, costs;
- conflict interaction in the system of equations has the character of parametric control;
- system dynamics equations are used as the equations of motion.

In the approach under consideration, three unified modules are used as the components of the models. They describe conflict interaction, increase in and participants' winnings and losses. Then, the model architecture will be represented as a connected set of three-component models, built on the basis of the same scheme. Such a set of component models contains models of conflict interaction of virtual communities that describe the movement of conflict elements and their relationships; virtual community benefit models that describe the effects of conflict interaction; models of expenditures of virtual communities on information confrontation; connection of models of winnings and costs of virtual communities with conflict model.

The conflict is that the gain of one virtual community is equal to the loss of another, or the increase in the number of supporters of vaccination is associated with a decrease in the number of supporters of the anti-vaccination movement.

$$\begin{cases} \frac{dx(t)}{dt} = f\left(x(t), a, u\right), \\ \frac{dy(t)}{dt} = f\left(y(t), b, v\right); \end{cases} \quad (1)$$

where $x(t)$, $y(t)$ – the number of actors of opposing virtual communities in the SNS information space; a, b – parameters of conflict interaction; u, v – control parameters.

The component of the model describes the gains of the virtual community as a result of conflict engagement as the growth of the certain resource associated with interests that are the cause of the conflict. In particular, such a resource is a portion of the SNS information space that is formed directly by the actor-carrier of the given narrative. The payoff model can be considered as assessment of the efficiency of conflict interaction for determination of the function of conflict effectiveness

$$\begin{cases} \frac{dr(t)}{dt} = f\left(r(t), c, u\right), \\ \frac{ds(t)}{dt} = f\left(s(t), d, v\right); \end{cases} \quad (2)$$

where $r(t)$, $s(t)$ – the variables that characterize the gain growth – the part of the SNS information space formed and controlled by the virtual community actors; c, d – parameters of conflict interaction of virtual communities in SNS; u, v – control parameters.

The cost model formalizes the growth of some cost-related resource that accompanies the conflict of virtual communities in the SNS information space. Such a resource is the cash costs spent on trolls' payments, time outlay used to achieve the goal of the conflict, the cost of technical support for conducting information war, etc. The expenditure model can also be seen as a characteristic for assessing conflict interaction to determine the effectiveness of conducting the information confrontation in SNS. In general, it takes the following form

$$\begin{cases} \dfrac{dp(t)}{dt} = f\left(p(t), g, u\right), \\ \dfrac{dq(t)}{dt} = f\left(q(t), h, v\right); \end{cases} \quad (3)$$

where $p(t)$, $q(t)$ – variables that characterize the costs of conflict interaction of virtual communities; g, h – parameters of interaction in SNS; u, v – control parameters.

As a result, the chosen model allows to simulate the processes of information confrontation of virtual communities on the example of antagonistic conflict in the SNS information space by varying the parameters of the three-layer model. It is advisable to present the developed conceptual model as a structural diagram, the form of which is shown in Fig. [1].

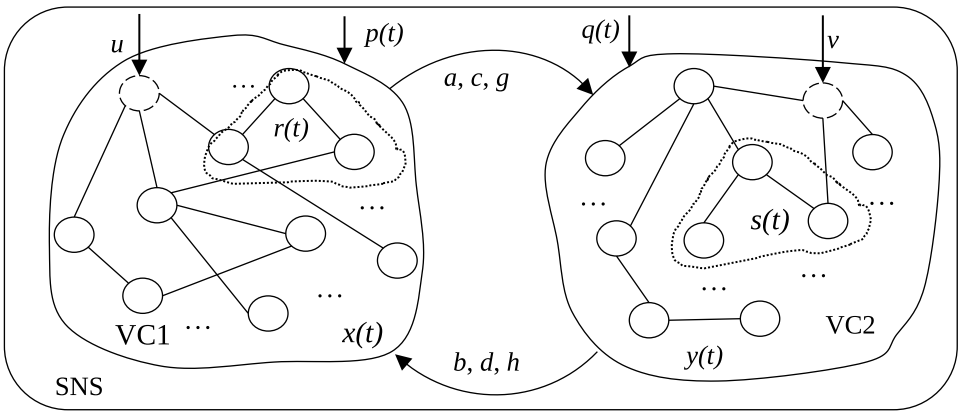

Fig. 1. Structural scheme of modelling of conflict interaction of virtual communities in SNS

Therefore, the behaviour of the virtual community in the context of conflict interaction in the SNS is set by the parameters a, c, g for the first group of actors and by b, d, h for the second group of actors. As the result of the change of these parameters, the number of actors in the corresponding virtual communities $x(t)$ and $y(t)$ also changes. This causes the changes of the resources of the communities of actors $r(t)$ and $s(t)$. In this case, the amount of resources spent on conducting counter-party information operations in the SNS is determined by the functions $p(t)$ and $q(t)$. Control vectors u and v for virtual communities provide the change of the parameters of conflict interaction according to a certain law.

Thus, the structural models of the parties of the conflict contain three components each and take the following form:

- the model of virtual community 1

$$\begin{cases} \frac{dx(t)}{dt} = f\left(x(t), a, u\right), \\ \frac{dr(t)}{dt} = f\left(r(t), c, u\right), \\ \frac{dp(t)}{dt} = f\left(p(t), g, u\right); \end{cases} \tag{4}$$

- the model of virtual community 2

$$\begin{cases} \frac{dy(t)}{dt}) = f\left(y(t), b, v\right), \\ \frac{ds(t)}{dt} = f\left(s(t), d, v\right), \\ \frac{dq(t)}{dt} = f\left(q(t), h, v\right). \end{cases} \tag{5}$$

2.3 Choice of the type of differential equation for the model of conflict interaction of virtual communities in SNS

The choice of the type of differential equation of the dynamics of information confrontation of virtual communities is an important issue from the point of view of the study of conflict interaction in the SNS information space. Let us choose the function of limited growth to formalize the conflict interaction of virtual community actors, which combines accelerated growth in the initial phase and accelerated deceleration in the final phase of antagonistic conflict. Such kind of differential equation includes control parameters [21]. Therefore, we choose the general equation of limited growth in the form of a second-order nonlinear differential equation as the equations of conflict dynamics [22]

$$a_2 w(t) \frac{d^2 w(t)}{dt^2} + \left(1 + a_1 w(t)\right) \frac{dw(t)}{dt} + \left[a_0 w(t) - \beta^+\right] \vartheta w^\theta(t) = 0\,, \tag{6}$$

where $w(t)$ – the studied indicator of conflict interaction; a_2, a_1, a_0 – parameters that represent vectors of latent control; ϑ, θ – parameters of multiplication of variables.

There is some characteristic value W for solving the differential growth equation $w(t)$, for which all components of expression (6) become zero at

$$\frac{d^2w(t)}{dt^2} \approx 0, \ \frac{dw(t)}{dt} \approx 0, \ a_0 w(t) - \beta^+ \approx 0. \quad (7)$$

The value $W = \beta^+ / a_0$ is called the threshold of the function of limited growth, to which the values of the state variables at large values of the time interval direct asymptotically. Thus W – is a characteristic parameter of the function of limited growth that physically determines some limit value that studied value can reach.

From general equation (6) we can obtain partial cases, among which we emphasize those that have a threshold character [23, 24] (Table [1]).

Table 1. Partial cases of the general equation of limited growth

	Name of the equation of limited growth	Conditions	The form of the equation of limited growth
1	the second order constrained growth equation		$a_2 ww'' + (1 + a_1 w)w' + \lfloor a_0 w - \beta^+ \rfloor w = 0$
2	first order restricted growth equation	$a_2 = 0$	$(1 + a_1 w)w' + \lfloor a_0 w - \beta^+ \rfloor w = 0$
3	first order constrained growth equation (Verhulst logistic equation)	$a_2 = 0$, $a_1 = 0$	$w' + \lfloor a_0 w - \beta^+ \rfloor w = 0$

All growth equations are characterized by a common element $(a_0 w(t) - \beta^+)$ used to determine the threshold. Since the logistic equation is a particular case of the differential growth equation (6), the equilibrium region of the growth equation is valid for it. Although for the implementation of component models (1) – (3) any equations in Table [1] can be used, the most constructive approach is the application of the first order constrained growth equation

$$(1 + a_1 w(t))\frac{dw(t)}{dt} + [a_0 w(t) - \beta^+]w(t) = 0. \quad (8)$$

The threshold of the function of limited growth W is considered as a parametrically dependent value. The solution of this differential equation is the function of growth of the investigated value, which is a description of the conflict of virtual communities in the SNS.

2.4 Layered representation of the dynamics of the model of conflict interaction of virtual communities in SNS

Let's present separate layers of the equation of the model of conflict dynamics based on the limited growth of the first order [21]:

1. The first layer of the model describes the dynamics of the number of two virtual communities – supporters $x(t)$ and $y(t)$ opponents of vaccination who are in antagonistic conflict

$$\begin{cases} \left(1+ax(t)\right)\dfrac{dx(t)}{dt}+\psi\left(\dfrac{x(t)}{X}-1\right)x(t)=0, \\ \left(1+by(t)\right)\dfrac{dy(t)}{dt}+\varphi\left(\dfrac{y(t)}{Y}-1\right)y(t)=0; \end{cases} \tag{9}$$

where a, b – the parameters that prevent the increase in the number of actors of the corresponding virtual communities in the SNS; ψ, φ – exponential growth indicators contributing to the growth of the number of actors; X, Y – limit values of the number of actors of opposing virtual communities.

For curves that describe limited growth, characteristic parameters $X=\psi/a$ and $Y=\varphi/b$ that limit the growth in the number of actors in the respective virtual communities are important. The conflict of actors is manifested in the fact that their total number is considered to be constant $x(t)+y(t)=n(t)=const$, $X(t)+Y(t)=N(t)=const$, and each virtual community tries to increase its number;

2. The second layer of the model formalizes the growth of resources $r(t)$ and $s(t)$ – corresponding benefits of virtual communities

$$\begin{cases} \left(1+cr(t)\right)\dfrac{dr(t)}{dt}+\alpha\left(\dfrac{r(t)}{R}-1\right)r(t)=0, \\ \left(1+ds(t)\right)\dfrac{ds(t)}{dt}+\beta\left(\dfrac{s(t)}{S}-1\right)s(t)=0; \end{cases} \tag{10}$$

where c, d – parameters that adversely affect the level of winnings resulting from information confrontation in the SNS; α, β – exponential growth rates of gain; R, S – thresholds for the winnings of virtual communities.

For curves, the characteristic parameter that limits the gain growth $R=\alpha/c$, $S=\beta/d$ is important. In this case, the limit values of the resources $r(t)$ and $s(t)$ depend on the threshold values of the number of actors of virtual communities in SNS $x(t)$, $y(t)$. At the same time the amount of winnings is not constant, which is connected with the non-deterministic behaviour of the actors in the SNS information space.

3. The third layer of the model characterizes the dynamics of resource expenditures for information confrontation in SNS

$$\begin{cases} \left(1+gp(t)\right)\dfrac{dp(t)}{dt}+\zeta\left(\dfrac{p(t)}{P}-1\right)p(t)=0, \\ \left(1+hq(t)\right)\dfrac{dq(t)}{dt}+\xi\left(\dfrac{q(t)}{Q}-1\right)q(t)=0; \end{cases} \tag{11}$$

where g, h – the parameters that negatively affect the cost level; ζ, ξ – intensity of expenditures for conducting operations (exponential growth rates); P, Q – the maximum amount of resources allocated for conducting the conflict $P=\zeta/g$, $Q=\xi/h$. The amount of resources spent on information warfare is also variable.

2.5 Relationship between threshold values of the number of virtual community actors and resources spent

Resource limits $r(t)$ and $s(t)$ depend on the thresholds of the number of actors $x(t)$, $y(t)$. In simple cases, we restrict ourselves to a linear dependence in the form $R=\lambda X$, $S=\mu Y$. At the same time, resource limit values depend on the thresholds values of the number of virtual communities actors involved in the conflict $S=f(Y)$, $R=f(X)$, $P=f(X)$, $Q=f(Y)$.

The nature of communication depends on the investigated aspect of the subject area. In simple cases, it is possible to limit ourselves to a linear dependence of the form $S=\mu Y$, $R=\lambda X$ that sets the scale of the output function. For linear dependence, there may occur difficulties connected with the decrease of the value of the function $y=f(t,u,v)$ in time. Let's assume that as the number of actors of the virtual community in a state of conflict decreases, then the winnings and resources of this community in the management of information warfare also decreases. Suppose that these quantities will vary in a complex way, which is related to the inverted S-shaped nature of the function $y=f(t,u,v)$ and the requirement to fulfill the condition $x+y=z$. However, a non-inverted S-function must be used to describe the benefits and expenditure of resources. To resolve this discrepancy, we use the following technique.

As a function of movement of gained resources and expense of resources we will use the functions of the limited growth with a variable value of a threshold, where the current values of the function of the original are used as the threshold, i.e. $R=f(x)$, $S=f(y)$, $P=f(x)$, $Q=f(y)$. Such dependence of threshold values is algorithmic and can be considered as a way of parametric control of movement of resources. Such functions can be convex in nature, which distinguishes them from the classic S-shaped features that have a monotonous growth pattern. Thereby, the constrained growth functions with a variable threshold value describes the relationship with the inverse S-function more adequately.

3 Experiments

To implement the computational experiment, we write the first layer of the model of antagonistic conflict of virtual communities in the SNS information space (9) in the form of a system of recurrent equations

$$\begin{cases} x_{k+1} = \left(1 + \psi \dfrac{1 - \dfrac{x_k}{X}}{1 + a x_k}\right) x_k, \\ y_{k+1} = \left(1 + \varphi \dfrac{1 - \dfrac{y_k}{Y}}{1 + b y_k}\right) y_k, \\ x_k + y_k = n_k,\ X + Y = N. \end{cases} \quad (12)$$

The limit values of the numbers of virtual communities of supporters X and opponents Y of vaccination are considered as desirable values of the number of carriers of a certain narrative as a result of conducting information confrontation in the SNS. We write the layers (10) – (11) in the form of recurrent formulas similarly to the expression (12).

The results of a study [25] showed that a rigid stance against vaccinations is supported only by a small number of parents, whereas various forms of “vaccine scepticism” and uncertainty about the need for vaccination are more widely spread. Less than 2% of parents fully reject vaccination, while selective or late vaccination is practiced by 2% to 27% of parents. “Vaccine hesitant” are from 20% to 30% of parents [25].

To conduct computational experiment, let us consider the situation where the number of actors in SNS who oppose vaccination has reached the critical mark of 30% - the value that precedes the start of the epidemic. To reduce the threat of the epidemic, let’s consider the following scenario: as a result of preventive work, in particular in the SNS information space, the number of vaccine opponents is reduced to 5%, and the number of vaccination supporters is increased to 95% (Fig. [2]).

The speed of change depends on the values of the control parameters a and b which are determined by the level of unacceptance by the actors of the relevant virtual communities of the narrative concerning the importance of early vaccination in order to prevent epidemics. It is possible to reduce the value of these parameters by transferring information to the virtual anti-vaccine community in an accessible form in order to influence their public opinion. The resulting values of the number of actors who are supporters and opponents of vaccination will be used as the current value of the conflict interaction function.

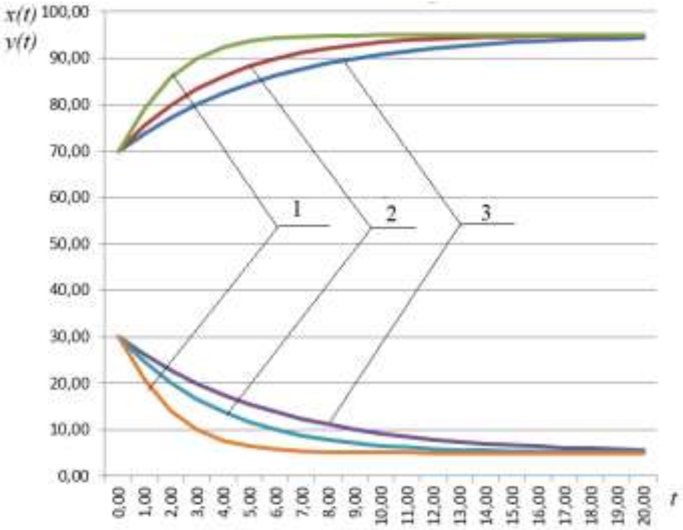

Fig. 2. Change in the number of supporters $x(t)$ and opponents $y(t)$ of vaccination to prevent epidemics at the following parameter values: 1 – $a=0$ and $b=0$; 2 – $a=0{,}01$ and $b=0{,}01$; 3 – $a=0{,}02$ and $b=0{,}02$

Fig. [3] shows the curves that describe the change in the normalized values of the information resource in the SNS and the costs of maintaining information warfare campaigns of the virtual community of vaccination supporters as a result of the redistribution of actors between the virtual communities (see Fig. [2]).

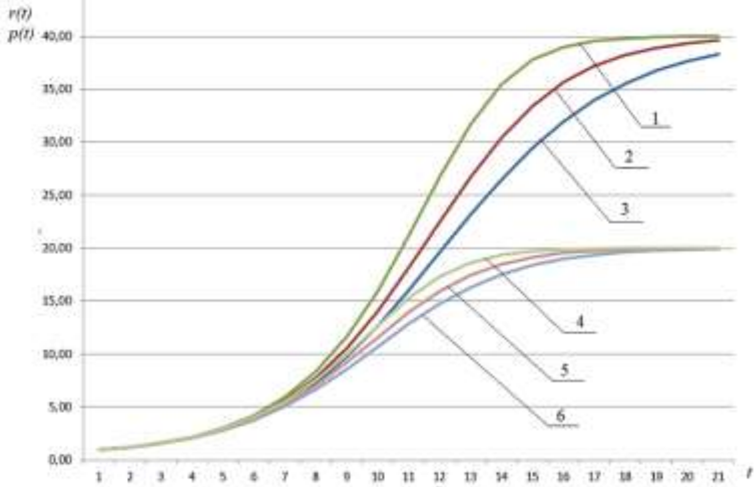

Fig. 3. Dynamics of benefit $r(t)$ at parameter values (curves 1–3) at $c = \{0;0{,}01;0{,}02\}$ and resource costs $p(t)$ (curves 4–6) for the virtual community of vaccination supporters at parameter values $g = \{0;0{,}01;0{,}02\}$

Fig. [3] shows that the value of the normalized benefit of the virtual community compared to the normalized value of the cost is 2 times higher. So every 1 conventional units the resource spent on information confrontation gives 2 conventional units gain in the context of the information resource in 20 days.

In Fig. [4] shows the dynamics of the normalized values of the information resource in the SNS and the costs of information warfare of the virtual community of the opponents of vaccination after the redistribution of actors between virtual communities in a state of conflict (see Fig. [2]).

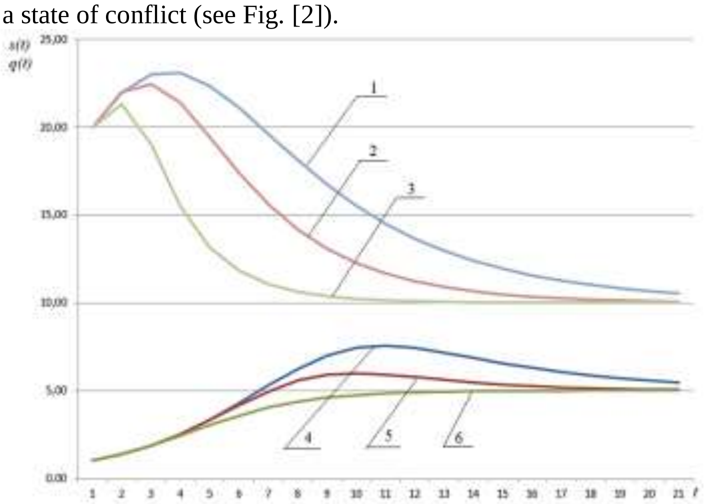

Fig. 4. Dynamics of resource expenditures $q(t)$ (curves 1–3) for $h = \{0{,}02;0{,}01;0\}$ and benefit $s(t)$ (curves 4–6) $d = \{0{,}02;0{,}01;0\}$ for the virtual community of vaccination advocates

Dependencies are described by convex curves, which is explained by the use of variable growth functions with variable thresholds. Also Fig. [4] shows that after 20 days each conventional unit of the resources spent on information warfare will give 0.5 of conventional units of gain in the virtual community information space, that is, resource expenditures are more than double the winning value. Such information confrontation between virtual communities is ineffective and will eventually lead to a further reduction in the number of opponents of the vaccination and significant losses of resources available for conflict interaction.

4 Conclusions

A three-layer model of conflict interaction of virtual communities in the SNS information space has been presented. It allows to formalize the processes of information confrontation on the example of the social anti- vaccination movement. The first layer of the model is used to formalize the conflict itself - the redistribution of actors between virtual communities as a result of conducting information operations. The second layer is intended to reflect the gain - the amount of SNS information resource that is controlled by the virtual community actors as a result of increasing the number of its actors. The third layer describes the expenditure of the resources for direct information combat in the SNS information space.

Each layer represents two differential equations that define the functions of limited growth for a particular aspect of the conflict interaction of virtual communities. The main characteristic parameter of such functions is the asymptotic threshold used to relate the equations to the system. The thresholds of winnings and losses functions depend on the thresholds of the functions describing the conflicting interaction of virtual communities. In this case, a variable-threshold approach is used for the winnings and losses functions. As the threshold value we use the current value of the conflict interaction function. The results of the modelling of conflict interaction of virtual communities in SNS allow to increase the effectiveness of the research of information confrontation processes and to develop effective measures to counter the threats to the information security of the state.

References

1. Popescu, E., Ghita, D.: Using social networking services to support learning. In: International Conference on Web-Based Learning, pp. 184–193. Springer, Berlin, Heidelberg (2013, October)
2. Salehan, M., Kim, D. J., Koo, C.: A study of the effect of social trust, trust in social networking services, and sharing attitude, on two dimensions of personal information sharing behavior. The Journal of Supercomputing **74**(8), pp. 3596–3619 (2018)
3. 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 **41**, pp. 55–73 (2018)
4. Trach, O., Peleshchyshyn, A.: Functional-network model of tasks performance of the virtual communities life cycle directions. In: Proceedings of the 11th International Scientific and Technical Conference, CSIT 2016, pp. 108–110 (2016) doi:10.1109/STC-CSIT.2016.7589881
5. Bilushchak, T., Komova, M., Peleshchyshyn, A.: Development of method of search and identification of historical information in the social environment of the internet. In: Proceedings of the 12th International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT 2017, pp. 196–199 (2017) doi:10.1109/STC-CSIT.2017.8098767
6. Peleshchyshyn, A., Markovets, O., Vus, V., Albota, S.: Identifying specific roles of users of social networks and their influence methods. In: Proceedings of 2018 IEEE 13th International Scientific and Technical Conference on Computer Sciences and Information Technologies, CSIT 2018 pp. 39–42 (2018) doi:10.1109/STC-CSIT.2018.8526635
7. Warrent, M. J., Hutchinsont, W.: Information warfare: Fact or fiction? (2017) doi:10.1007/978-0-387-35515-3_54
8. Kereselidze, N.: Combined continuous nonlinear mathematical and computer models of the information warfare. International Journal of Circuits, Systems and Signal Processing **12**, pp. 220–228 (2018)

9. Desouza, K.C., Ahmad, A., Naseer, H., Sharma, M.: Weaponizing information systems for political disruption: The Actor, Lever, Effects, and Response Taxonomy (ALERT). Computers and Security **88** (2020)
10. Miller, C.: Inside the information wars. New Scientist **244**(3252) pp. 38–41 (2019)
11. Peleschyshyn, A., Holub, Z., Holub, I.: Methods of real-time detecting manipulation in online communities. In: Computer Sciences and Information Technologies - Proceedings of the 11th International Scientific and Technical Conference, CSIT 2016, pp. 15–17 (2016). doi:10.1109/STC-CSIT.2016.7589857
12. Hryshchuk, R., Molodetska, K., Syerov, Y.: Method of improving the information security of virtual communities in social networking services. In: CEUR Workshop Proceedings **2392** pp. 23–41 (2019)
13. Hryshchuk, R., Molodetska, K.: Synergetic control of social networking services actors' interactions. In: Recent Advances in Systems, Control and Information Technology **543** pp. 34–42 (2017) doi:10.1007/978-3-319-48923-0_5
14. Korobiichuk, I., Snitsarenko, P., Katsalap, V., Hryshchuk, R.: Determination and evaluation of negative informational and psychological influence on the military personnel based on the quantitative measure. In: CEUR Workshop Proceedings **2392** pp. 66–78 (2019)
15. Broniatowski, D. A., Jamison, A. M., Qi, S., AlKulaib, L., Chen, T., Benton, A., Dredze, M.: Weaponized health communication: Twitter bots and Russian trolls amplify the vaccine debate. American journal of public health **108**(10), pp. 1378–1384 (2018)
16. Rajasekar, S.P., Pitchaimani, M., Zhu, Q.: Progressive dynamics of a stochastic epidemic model with logistic growth and saturated treatment. Physica A: Statistical Mechanics and its Applications **538** (2020).
17. Yao, Y., Li, Y., Xiong, X., Wu, Y., Lin, H., Ju, S.: An interactive propagation model of multiple information in complex networks. Physica A: Statistical Mechanics and its Applications **537** (2020).
18. The official website of the World Health Organization https://www.who.int/home
19. Salam, K. M. M., Takahashi, K. I.: Mathematical model of conflict and cooperation with non-annihilating multi-opponent. In: Minai A., Braha D., Bar-Yam Y. (eds) Unifying Themes in Complex Systems. Springer, Berlin, Heidelberg (2010) doi.org/10.1007/978-3-540-85081-6_38
20. Kuchar, J. K., Yang, L. C.: A review of conflict detection and resolution modeling methods. In: IEEE Transactions on Intelligent Transportation Systems **1**, 4 pp. 179–189 (Dec. 2000) doi: 10.1109/6979.898217
21. Molodetska, K., Tymonin, Yu., Melnychuk, I.: The conceptual model of information confrontation of virtual communities in social networking services. International Journal of Electrical and Computer Engineering **10**, no. 1(II) (Feb. 2020) http://ijece.iaescore.com/index.php/IJECE/article/view/20992
22. Molodetska, K., Tymonin, Y.: System-dynamic models of destructive informational influence in social networking services. International Journal of 3D Printing Technologies and Digital Industry **3**(2) pp. 137–146 (2019)
23. Molodetska, K., Tymonin, Y.: Synthesis of nonlinear feedback in business dynamics models. (in Russian). In: Yu. C. Ponomarenko, T.S. Klebanova (eds.) Tools for modeling systems in the information economy. Kharkiv, Higher School of Economics, Kuznets National Research University pp. 302–313 (2019)
24. Hrabar, I., Tymonin, Yu., Brodsky, Yu.: The universal model of the system: the methodological aspect. (in Ukrainian). Bulletin of ZhNAEU **1** pp. 202–209 (2009)

25. Leask, J., Kinnersley, P., Jackson, C., Cheater, F., Bedford, H., Rowles, G.: Communicating with parents about vaccination: a framework for health professionals. BMC pediatrics **12** pp. 154 (2012). doi:10.1186/1471-2431-12-154