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Information Warfare Model with Internal Conflict

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Abstract

We construct and study an information warfare model, with an internal conflict integrated into it (interregional migration) based on the example of the Lotka-Voltaire model with cyclical migration, as well as its research using a software tool. For this purpose, the behavior of the spread of one and several information threats within the same community is described, the principle of conflict is described, a model is built and its behavior is studied on various examples, and conclusions are drawn regarding the importance of the influence of internal conflict on the model and regarding methods of predicting the results.

KEY WORDS: *information warfare model, conflict interaction, the Lotka-Voltaire model, stochastic vector.*

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1. Introduction

Nowadays humanity has reached a new stage of its evolution – the so-called "information society". It is characterized by a sharp increase in the importance of the information sphere. And everything that is important to one degree or another creates new threats and dangers. With the emergence of the information sphere and its ever-growing role in our lives, there was a need for its regulation and, most importantly, its protection.

Therefore, the issue of information security is quite important now. Existing information dissemination technologies open up a huge space for the dissemination of various information, including harmful information in the form of propaganda. That is why, during the last decades, tasks to ensure the information order (information security) began to come to the fore. Their list includes problems related to determining the sources, nature, and mechanisms of the emergence and distribution of information flows, as well as various related tasks.

As we know, information can be of a different nature and with sufficient resources, it can be directed and used for various purposes, which are not always positive, but often on the contrary – have harmful and dangerous consequences. A proper understanding of the operation of information dissemination mechanisms is required for proper countermeasures against such threats and timely neutralization of negative effects, or their weakening. At the moment, there are a small number of really effective approaches that produce results. One of approaches is modeling.

The purpose of this work is to first study the model of informational struggle, which is based on the article [1]. The concept of conflict and one of the options for its implementation between indestructible rivals in the form of interregional migration will also be separately considered, in which we will refer to the article [2], [3], [5], [7], [9].

Papers [4], [6], [8] and [10–14] describe, respectively, the basic principles of the theory of continuous evolutionary models with impulse perturbations, and the actual continuous model of information warfare model. And the main task will be the creation of a complex system that will describe the model of information struggle with internal conflict integrated into it (interregional migration) based on the example of the Lotka-Voltaire model with cyclic migration, which is described in [2], as well as its research using a software tool. In the examples (Fig. 4–19), we will conditionally divide the territory into four regions and examine the model's behavior at various coefficients and with different migration directions.

2. "Classic" information warfare model

Let us start with setting the problem in the simplest case [1]. Let us have a social community with the number of N_0, potentially susceptible to the influence of two information streams dissimilar in their content (in the extreme case, information of type 1 (I_1) and type 2 (I_2) are diametrically opposed to each other). We assume at the time $t_0 = 0$ two sources of different information simultaneously begin to broadcast it, as a result of which both information flows spread among the community.

Since I_1 and I_2 are not similar to each other, this process can naturally be considered as an information struggle (competition, rivalry). Our goal now is to build a mathematical model of this struggle, from which it would be possible to obtain the dynamics of its development over time (that is, the dependence on time t of the values $N_1(t)$ and $N_2(t)$ – the number of "adepts" who perceived information, sources "1" and "2"), as well as determine its final result - "winner" or "loser". The winner will be considered to be the one who, by the time the studied community is fully covered by both types of information, has managed to spread his information among a larger number of community members than the opponent, i.e. a value greater than $N_0/2$.

Basic model assumptions. 1) Each of flows I_1 and I_2 is distributed among the community through two information channels:

a) the first of them is "external" in relation to the community. The speed of information propagation through this channel for I_1 is characterized by the parameter $\alpha_1 > 0$, and for I_2 - by the parameter $\alpha_2 > 0$, which are considered independent of time;

b) the second – "internal" channel - interpersonal communication of members of the social community (its intensity for I_1 is characterized by the parameter $\beta_1 > 0$, and for I_2 – by the parameter $\beta_2 > 0$, which are not dependent on time). As a result of such communication, the adepts already recruited by the idea "1" (their number is equal to the value of $N_1(t)$, influencing the members who have not yet been recruited (their number is equal to the value of $(N_0 - N_1(t) - N_2(t))$, contribute their "personal" contribution to the recruitment process. In the same way, the adepts recruited by the idea "2" (their number is equal to the value of $N_2(t)$), influencing the members who have not yet been recruited (their number is also equal to the value of $N_0 - N_1(t) - N_2(t)$), contribute their "personal" contribution to the recruitment process.

2) The rates of change in the number of followers $N_1(t) + N_2(t)$ (that is, the number of which was recruited in a unit of time I_1 and I_2) consist of:

a) rates of external recruitment (they are proportional to the products of parameters α_1 and α_2 on the number of active members $(N_0 - N_1(t) - N_2(t))$, i.e. values α_1 $(N_0 - N_1(t) - N_2(t))$ and α_2 $(N_0 - N_1(t) - N_2(t))$, respectively for I_1 and I_2;

b) rates of internal recruitment (they are proportional to the products of the parameters β_1 and β_2 on the number of active followers $N_1(t)$ and $N_2(t)$ and on those not yet recruited $(N_0 - N_1(t) - N_2(t))$, that is, the values of $\beta_1 N_1(t)$ $(N_0 - N_1(t) - N_2(t))$ and $\beta_2 N_2(t)$ $(N_0 - N_1(t) - N_2(t))$, for I_1 and I_2, respectively.

The number of not-yet-recruited members of the community is equal to N_0 without members who have already received not one, but both types of information (that is, the sum $N_1(t) + N_2(t)$), should be subtracted. As in item 1, the parameters $\alpha_1, \alpha_2, \beta_1$ and β_2 characterize not only the intensity of informational influence, but also the tendency to perceive it at the same time. Thus, the part of the community not yet recruited by the time t (its hypothetical "average statistical" representative, initially neutral in relation to both I_1 and I_2) accepts information faster if the values of $\alpha_1, \alpha_2, \beta_1$ and β_2 are larger. At the same time, even if the influence of I_1 is clearly greater than that of I_2 (i.e. $\alpha_1 > \alpha_2, \beta_1 > \beta_2$), some members of the community still accept I_2 (i.e. there is no complete monopoly of one type of information over another).

Summarizing assumptions 1 and 2, we get the model [1]:

$$\begin{cases} \frac{dN_1}{dt} = \left(\alpha_1 + \beta_1 N_1(t)\right)\left(N_0 - N_1(t) - N_2(t)\right), N_1(t_0 = 0) = N_1(0) \geq 0 \\ \frac{dN_2}{dt} = \left(\alpha_2 + \beta_2 N_2(t)\right)\left(N_0 - N_1(t) - N_2(t)\right), N_1(t_0 = 0) = N_2(0) \geq 0 \end{cases} \quad (1)$$

The system of nonlinear ordinary differential equations (1) (autonomous dynamic system of the 2nd order) is the initial model of the researched process. From it, given the known parameters $N_0, \alpha_1, \beta_1, \alpha_2, \beta_2$ and the initial values of the quantities $N_1(0)$ and $N_2(0)$, it is possible to analytically or numerically find all the required characteristics. Dividing the second equation (1) by the first, we get:

$$\frac{dN_2}{dN_1} = \frac{\alpha_2 + \beta_2 N_2}{\alpha_1 + \beta_1 N_1} \quad (2)$$

Hence, we find the joint solution of system (1) in the form of an integral:

$$\beta_2 N_2(t) = C\left(\alpha_1 + \beta_1 N_1(t)\right)^{\frac{\beta_2}{\beta_1}} - \alpha_2 \quad (3)$$

$$C = \frac{\alpha_2 + \beta_2 N_2(0)}{\left(\alpha_1 + \beta_1 N_1(0)\right)^{\frac{\beta_2}{\beta_1}}}$$

In particular, with zero initial data ($N_1(0) = N_2(0) = 0$) the integration constant is equal to $C = \frac{\alpha_2}{\alpha_1^{\frac{\beta_2}{\beta_1}}}$, and we have for the equation's solution

$$\frac{\beta_2}{\alpha_2} N_2(t) = \left(1 + \frac{\beta_1}{\alpha_1} N_1(t)\right)^{\frac{\beta_2}{\beta_1}} - 1 \quad (4)$$

We also note that it is possible to find a condition for the victory of one type of information over another by introducing the "victory" function V_i [1]:

$$V_i = V_i(\alpha_i, \beta_i, N_i(0), N_0), i = 1,2,$$

where

$$V_i = \beta_i \ln\left(\left(1 + \frac{\beta_i N_0}{2a_i}\right) / \left(1 + \frac{\beta_i N_i(0)}{2a_i}\right)\right)^{-1}$$

Then the participant with the highest value of the victory function will be considered the winner.

3. Examples of the behavior of models in the simple cases

For clarity, we will use a discrete-time model. To do this, we will use the definition of the derivative:

$$\frac{dN_i}{dt} = \frac{\Delta N}{\Delta t} = \frac{N_i^{(n+1)} - N_i^{(n)}}{1}$$

where $n \in (0, \infty)$ is time. We received a discrete form of the model of information struggle (1):

$$\begin{cases} N_1^{(n+1)} = \left(\alpha_1 + \beta_2 N_1^{(n)}\right)\left(N_0 - N_1^{(n)} - N_2^{(n)}\right) + N_1^{(n)} \\ N_2^{(n+1)} = \left(\alpha_2 + \beta_2 N_1^{(n)}\right)\left(N_0 - N_1^{(n)} - N_2^{(n)}\right) + N_2^{(n)} \end{cases} \quad (5)$$

Next, we consider several illustrative examples that demonstrate the behavior of the model for various parameters.

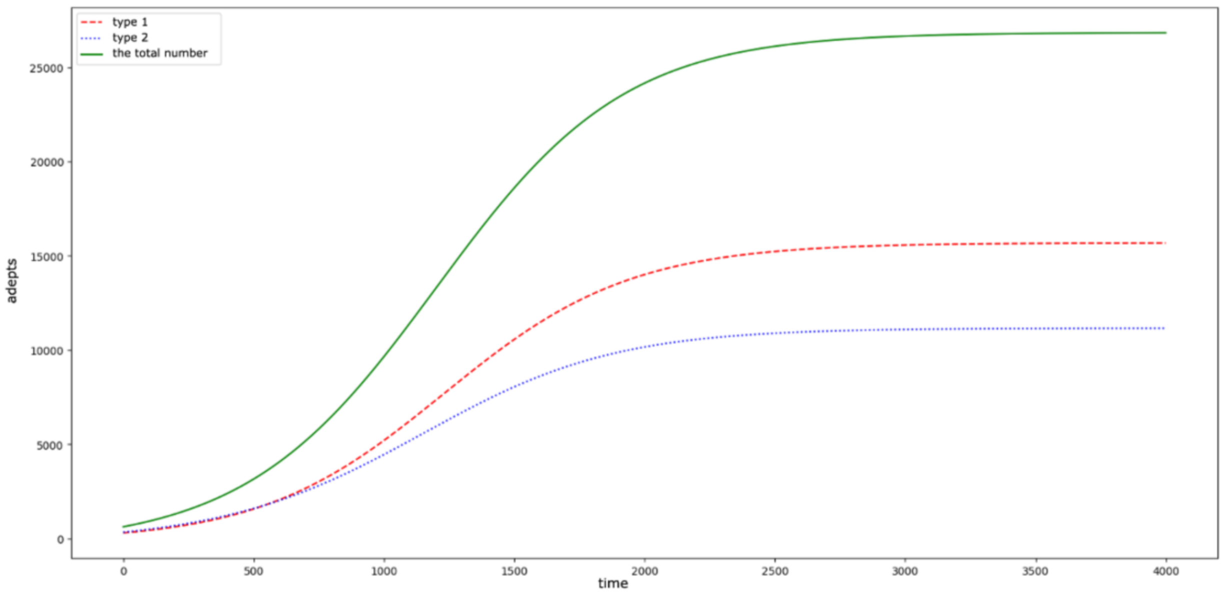

Fig. 1 Model example 1

Consider the behavior of a model with non-zero initial numbers of followers $N_1(0) = 289, N_2(0) = 326, N_0 = 26840$ at parameters values: $\alpha_1 = 0.000015, \alpha_2 = 0.000025, \beta_1 = 0.00000011, \beta_2 = 0.000000089355$. With the help of computer support, we will build a graph and calculate the values of the victory functions

$$V_1 = 3.177659836624433 \cdot 10^{-8}$$

$$V_2 = 2.865215480796103 \cdot 10^{-8}$$

As we can see from Fig.1, the values of the victory function coincided with the results – type 1 information won the fight.

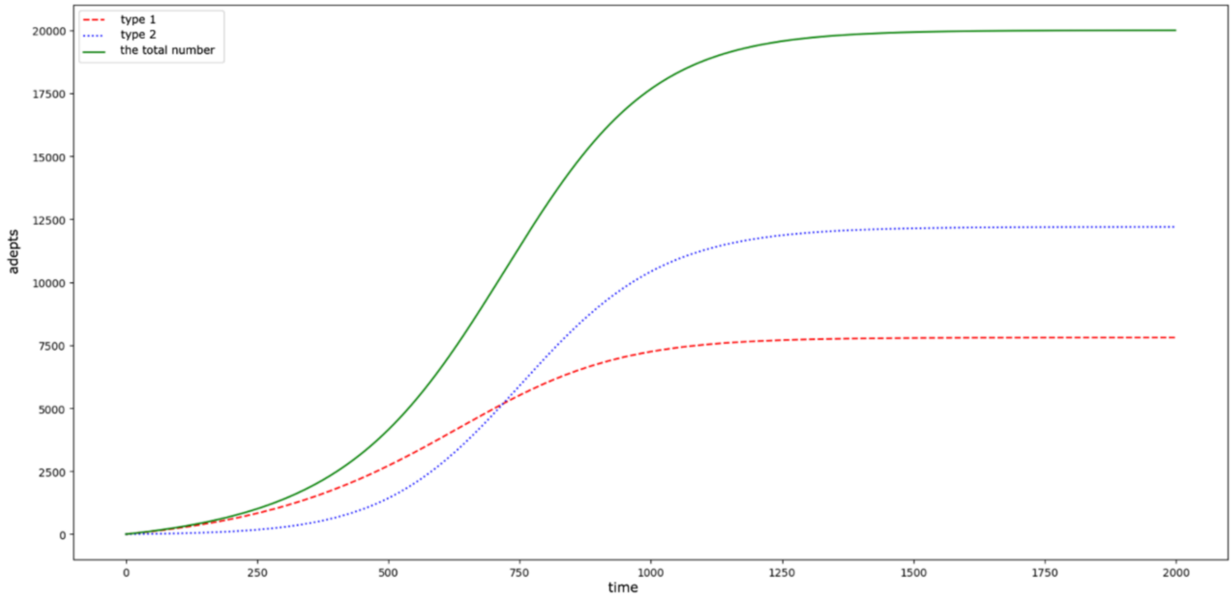

Fig. 2 Model example 2

$\alpha_1 = 0.0001, \alpha_2 = 0.00001, \beta_1 = 0.0000002, \beta_2 = 0.00000045, N_1(0) = 0, N_2(0) = 0, N_0 = 20000$

$$V_1 = 6.569174775061021 \cdot 10^{-8}$$

$$V_2 = 7.363207148164498 \cdot 10^{-8}$$

This example 2 shows a slightly different scenario of the model's behavior: although the final result indicates a clear victory of type 2, at the beginning type 1 held the lead, which indicates the possibility of a change of leadership at any time until the community is covered by followers. It is easy to imagine a situation when information about the intermediate behavior of the model can be important, which even in the case of such a simplified model of the information struggle, suggests that the victory function is not such a useful tool compared to modeling.

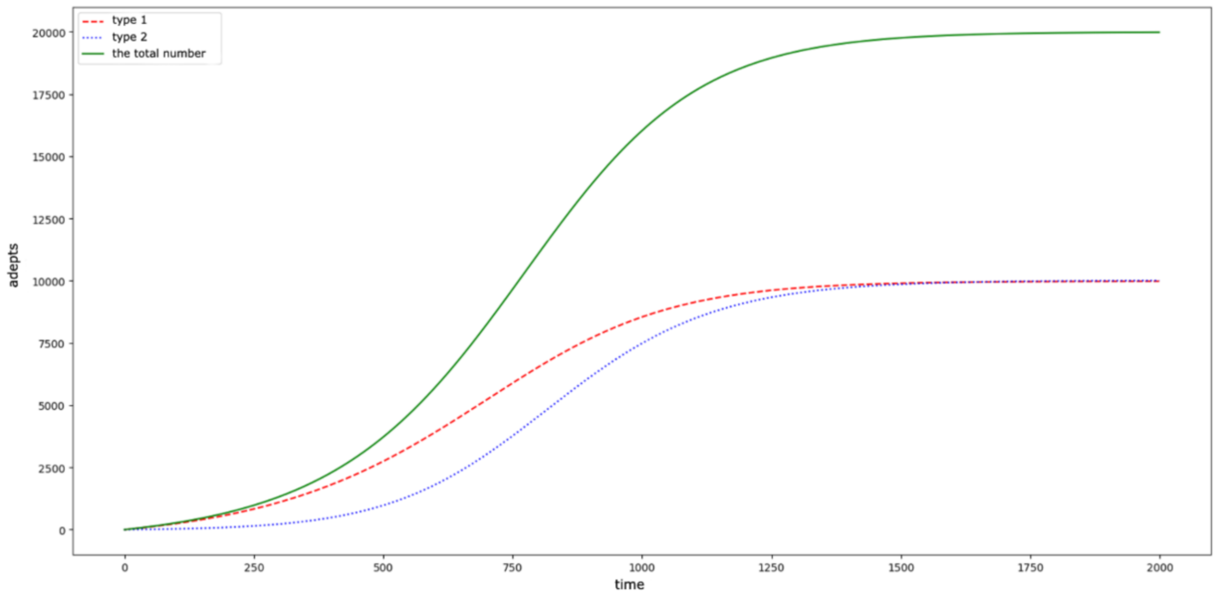

Fig. 3. Model example 3

$\alpha_1 = 0.0001, \alpha_2 = 0.00001, \beta_1 = 0.0000002, \beta_2 = 0.00000039326, N_1(0) = 0, N_2(0) = 0, N_0 = 20000$

$$V_1 = 6.569174775061021 \cdot 10^{-8}$$

$$V_2 = 6.57959947580904 \cdot 10^{-8}$$

In case of example 3, type 1 dominated for a while but eventually caught up with type 2, which was "predicted by the win function." Parity is established, but should intermediate values be completely ignored? If there was a clear lead for a certain period of time, and then there was no one, then did type 1 not get some other achievement besides winning.

Any, including intermediate values, can be important in various tasks, especially when it comes to information security [15,16]. But in any case, it can be said with certainty that it is the modeling of behavior over long intervals that brings the desired results and that the final value does not even come close to describing the general behavior.

4. Model of conflict interaction between complex systems

By conflict we will understand a physical system consisting of at least two substances (opponents) A and B, and a certain field of common interests Ω (the field of common interests consists of "positions", each of which at one moment in time can belong to only one substance or be free), which they are interested in capturing [2], [3]. We consider one of the simplest variants of a complex system, in which the field of common interests is divided into a finite number of separate regions $\Omega_i: \Omega = \cup_{i=1}^{n} \Omega_i, n < \infty$. The goal of each of the opponents A and B is to own as many positions as possible in Ω. This means that A and B can be described by vectors with non-negative coordinates: $A = (A_1, \dots, A_n)$, $B = (B_1, \dots, B_n)$, $A_i, B_i \geq 0, i = 1, \dots, n$, and their initial values describe the starting positions of the opponents and can be both zero and non-zero. At the same time, the numbers A_i, B_i give the quantitative characteristics of the corresponding substances in Ω_i at any moment in time.

The change of vectors A and B caused by conflict interaction gives rise to some dynamic system in discrete time:

$$\{A^N, B^N\} \overset{*}{\rightarrow} \{A^{N+1}, B^{N+1}\}, N = 0,1, \dots, \tag{6}$$

where A^0 and B^0 characterize the substances at the initial moment of time.

The reflection * denotes the law of this conflict interaction between substances, which is generally unknown. Here we will define it according to our intuitive understanding of the physical meaning of substances A and B within the framework of our problem and according to the conditions imposed by the studied model.

As we wrote earlier our goal is to describe the model of information struggle with internal conflict, by which we understand some interregional interaction as migration, following the example of the Lotka-Voltaire model with cyclical migration [1].

To describe the principle of migration, which will be the law of interaction between substances (within the framework of this problem), we will use the model of conflict interaction in a discrete-time system between two indestructible rivals [3] (the indestructibility of rivals is an important condition, the satisfaction of which corresponds to the assumptions of the model information struggle). We are especially interested in the rule of redistribution of values, described by the formula of non-linear and non-commutative conflict interaction between two vectors, which we will use later.

$$p_i^{(n+1)} = \frac{p_{ai}^{(n)}\left(1+\gamma r_i^{(n)}\right)}{1+\gamma \sum_{i=1}^{I} p_i^{(n)} r_i^{(n)}} \tag{7}$$

This formula describes the change in the quantitative values of the substance p in the regions under the influence of the substance r with a certain coefficient in the field of interest (the total amount of the substance does not change). The result of such an interaction depends on the distribution of substances and the coefficient of their interaction. In the framework of the indestructibility of opponents, this interaction is reduced to the movement (outflow) of substances from one region to another. The magnitude of this outflow depends on the value of the intensity coefficient $\gamma \epsilon [0,1]$, and its sign indicates the direction of movement relative to the magnitude of another substance in the regions. These coefficients do not necessarily have to be equal for the interaction of p with r and r with p, as they describe independent outflows. That is, the first substance can interact with the other more than the second with the first, which makes this formula more universal. With a positive intensity coefficient during the interaction of substances p with r (which is described by formula (2)), some part of substance p in all regions will flow to places where there is more substance r and vice versa. For example, in the case of two regions, in the region with a larger amount of r, the amount of p will increase, and in the second, where it is less, it will decrease by the same amount. With a larger number of regions, the redistribution is less obvious, but the idea of the principle remains.

It is also worth remembering that as a result of such interactions, the total value of each region $\Omega_i = \text{substance } r + \text{substance } p + \text{free positions}$, but not Ω, can change at each moment of time.

In formula (7), normalized (stochastic) vectors are used for calculations. And since we use natural numbers to describe the amount of substance (members of the community), before and after calculations, the necessary vectors must be normalized and denormalized accordingly:

$$\tilde{p}_i = \frac{p_i}{z}, z = \sum_{i=1}^{I} p_i \tag{8}$$

$$p_i = \tilde{p}_i z \tag{9}$$

where I is the number of regions, p_i is the absolute amount of substance p in the region i, and we is a normalized vector.

Since the basis of our model is still the model of informational struggle within a certain community, we are forced to impose a number of intuitive conventions in order to preserve the possibility of further complicating the model for practical application.

As it was said earlier, the parties to the conflict are 2 types of information I_1 and I_2, the field of interests will be a conditional community. Next, let us "settle" our community on some territory and divide it into regions. This, in addition to satisfying the necessary conditions for the integration of the conflict in the model, brings the problem closer to real practical conditions. Each element of such a community, according to the assumptions made in section 1, can be an adept of information of one of the types or a so-called neutral personality - a neutral. The conflict interaction itself will take place at each moment of discrete time. Adepts of information, as well as the neutrals themselves, will be interacting substances, respectively. However, this is not a conflict between three equal players, since neutrals also play the role of a field of interests, but a conflict between adepts of different types of information and at the same time – a conflict between all adepts and neutrals (because it is natural to assume that neutral members of the community also have respond to changes). Therefore, we will divide the entire interaction into two stages:

(I) The conflict between neutrals and adepts of information in general
(II) Conflict between adherents of different types of information

During the first stage, the redistribution of the vector of neutrals N_0 will take place under the influence of the vector of the sum of followers in each region $N_{(1+2)}$ and the coefficient α, and the vectors N_1 and N_2 will be influenced by the vector of neutrals and the coefficient γ (if necessary, you can use different interaction coefficients, but we will limit ourselves to one). In the second stage, a standard conflict between two players will take place: the vectors of followers are redistributed under the influence of the opponent's vector and the coefficient β (as above, we can take the coefficient for each interaction).

We will fix the state of our system by three vectors and a moment of time: $N_1^{(n)} = \left(N_{11}^{(n)}, \dots, N_{1i}^{(n)}\right), N_2^{(n)} = \left(N_{21}^{(n)}, \dots, N_{2i}^{(n)}\right)$ are the distributions of the number of all persons, $N_0^{(n)} = \left(N_{01}^{(n)}, \dots, N_{0i}^{(n)}\right)$ is the distribution of neutral persons, $(N_0^{(n)} = N^{(n)} - N_1^{(n)} - N_2^{(n)}$, where $N^{(n)}$ with non-negative coefficients, $n = 0,1, \dots$ describes discrete time, $i \in N_+$ is the number of the conflict region.

The schematic evolution of the vectors will look like this:

$$N_1^{(n)}\left(N_2^{(2)}\right) \xrightarrow{information\ warfare\ model} N_1^{(ń)}\left(N_2^{(ń)}\right) \xrightarrow{the\ conflict\ of\ adepts\ and\ neutrals} N_1^{(n'')}\left(N_2^{(n'')}\right)$$

$$\xrightarrow{the\ conflict\ of\ adepts\ and\ neutrals} N_1^{(n+1)}\left(N_2^{(n+1)}\right)$$

$$N_0^{(n)} \xrightarrow{information\ warfar\ model} N_0^{(n')} \xrightarrow{the\ conflict\ of\ adepts\ and\ neutrals} N_0^{(n+1)}$$

where n' and n'' mean intermediate moments of evolutionary cycles.

The general algorithm of the program during one round in the cycle will be as follows: First of all, we recalculate the vectors of adepts 1 and 2 of the information type coordinately according to the formulas from chapter 2:

$$\begin{cases} N_{1i}^{(n')} = (\alpha_1 + \beta_2 N_{1i}^{(n)})(N_i^{(n)} - N_{1i}^{(n)} - N_{2i}^{(n)}) + N_{1i}^{(n)} \\ N_{2i}^{(n')} = (\alpha_2 + \beta_2 N_{2i}^{(n)})(N_i^{(n)} - N_{1i}^{(n)} - N_{2i}^{(n)}) + N_{2i}^{(n)} \\ N_{0i}^{(ń)} = N_i^{(ń)} - N_{1i}^{(ń)} - N_{2i}^{(ń)} \end{cases}$$

Next, we will conduct a conflict interaction between all adepts and neutrals. To do this, we first form the vector of adepts $N_{1+2}^{(n')} = N_1^{(n')} + N_2^{(n')}$ (addition is coordinate-wise). We will describe this conflict with the following transition:

$$\begin{pmatrix} N_1^{(n')} \\ N_2^{(n')} \\ N_0^{(n')} \end{pmatrix} \xrightarrow{A} \begin{pmatrix} N_1^{(n'')} \\ N_2^{(n'')} \\ N_0^{(n'')} \end{pmatrix}$$

where A consists of three operations that we described earlier: $A = D^{-1} * D$, D and D^{-1} normalization and denormalization operations, respectively (formulas (8) and (9)), and * is the law of conflict interaction. Therefore, calculations will be made according to the following formulas:

$$N_{0i}^{(n+1)} = \frac{N_{2i}^{(ń)}\left(1 + \alpha N_{1+2i}^{(ń)}\right)}{1 + \gamma \sum_{i=1}^{I} N_{0i}^{(ń)} N_{1+2i}^{(ń)}}, N_{1i}^{(ń)} = \frac{N_{1i}^{(ń)}\left(1 + \gamma N_{0i}^{(ń)}\right)}{1 + \gamma \sum_{i=1}^{I} N_{1i}^{(ń)} N_{0i}^{(ń)}}, N_{2i}^{(ń)} = \frac{N_{2i}^{(ń)}\left(1 + \gamma N_{0i}^{(ń)}\right)}{1 + \gamma \sum_{i=1}^{I} N_{2i}^{(ń)}}, i = 1, \dots, I$$

Now we need to conduct a conflict between different adepts:

$$\begin{pmatrix} N_1^{(n'')} \\ N_2^{(n'')} \end{pmatrix} \xrightarrow{B} \begin{pmatrix} N_1^{(n+1)} \\ N_2^{(n+1)} \end{pmatrix},$$

$$B = D^{-1} \acute{*} D$$

Here by $\acute{*}$ we understand the following redistribution:

$$N_{1i}^{(n+1)} = \frac{N_{1i}^{(n'')}\left(1+\beta N_{2i}^{(n'')}\right)}{1+\beta\sum_{i=1}^{I} N_{1i}^{(n'')} N_{2i}^{(n'')}}, N_{2i}^{(n+1)} = \frac{N_{2i}^{(n'')}\left(1+\beta N_{1i}^{(n'')}\right)}{1+\beta\sum_{i=1}^{I} N_{2i}^{(n'')} N_{1i}^{(n'')}}$$

After that, we will recalculate the vector of all persons by region and finish the round.

5. Examples

In this section, we will consider the behavior of the created model by simulating its behavior with the help of the program. For greater visibility of the influence of internal conflict on the model of information struggle, we will take the parameters for the basic model from example 1 (Fig.1). It described an unequivocal victory of type I_1, both by the value of the victory function and by constant leadership.

Let the number of regions I be 4 and the initial distributions are as follows: $N_1^{(0)} = (31, 97, 73, 88), N_2^{(0)} = (34, 94, 122, 76), \mathrm{N}^{(0)} = (6746, 3464, 9790, 6840)$ $(N_1(0) = 289, N_2(0) = 326, N_0 = 26840)$. And then we will consider the behavior of the model with different coefficients of conflict interaction and, most importantly, with different signs because although the magnitude of the interaction is important, it is not as much as the direction of migration.

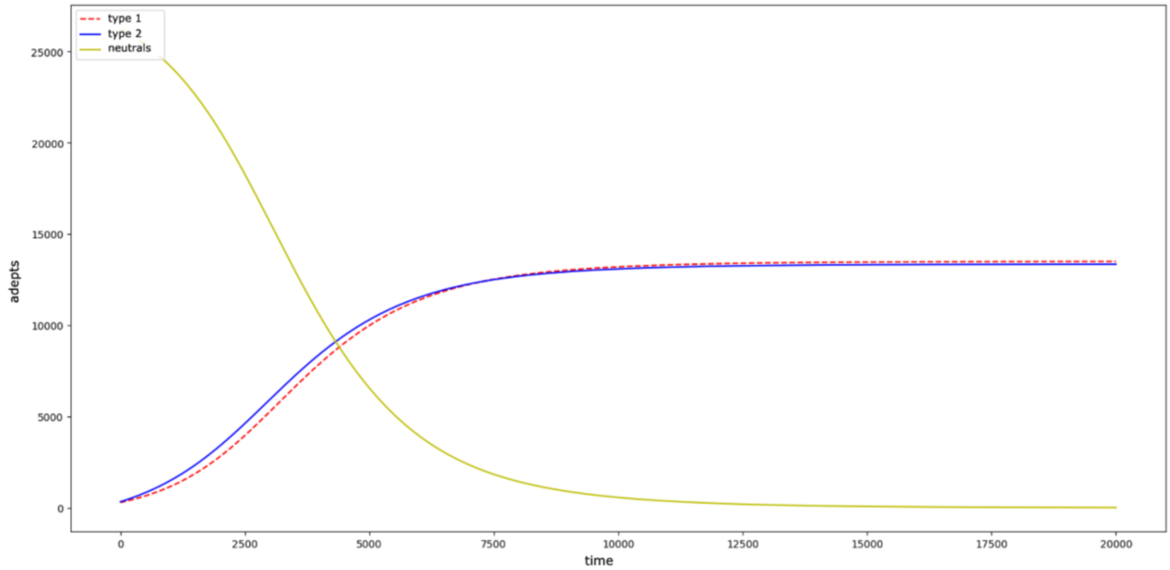

Fig. 4. General behavior of the model

5.1. The case with zero coefficients

First, consider the case when all coefficients α, β, γ are zero – that is, there is no conflict, but the division into regions remains.

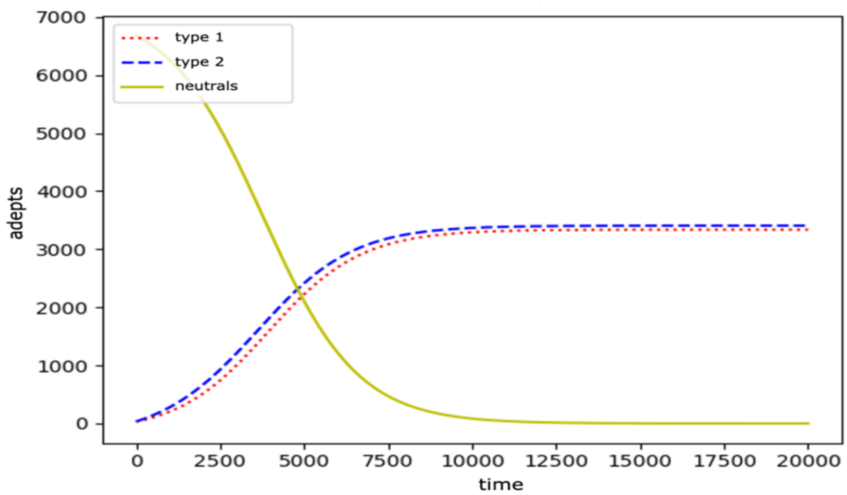

Fig. 5. Region 1

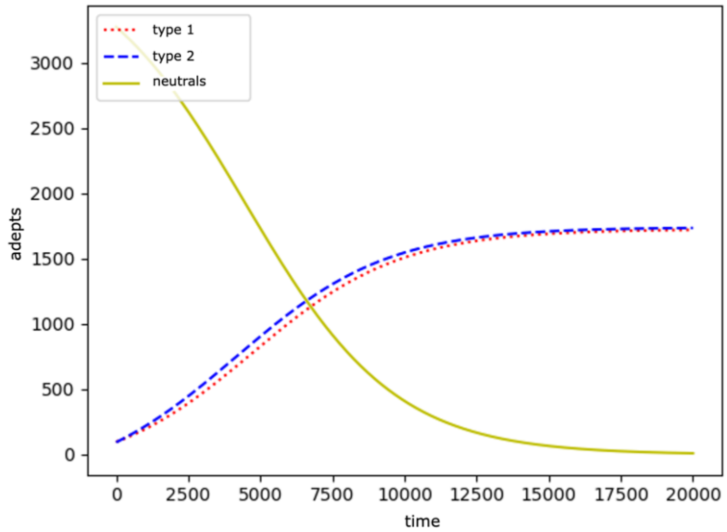

Fig. 6. Region 2

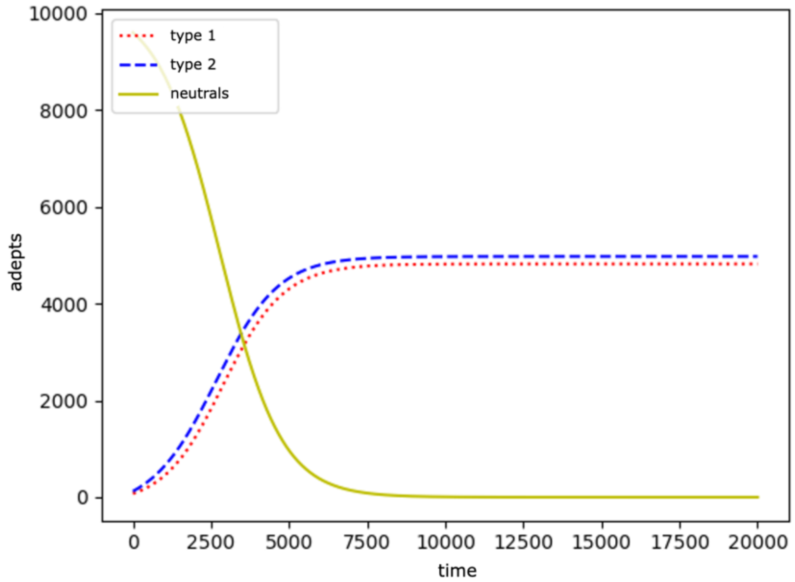

Fig. 7. Region 3

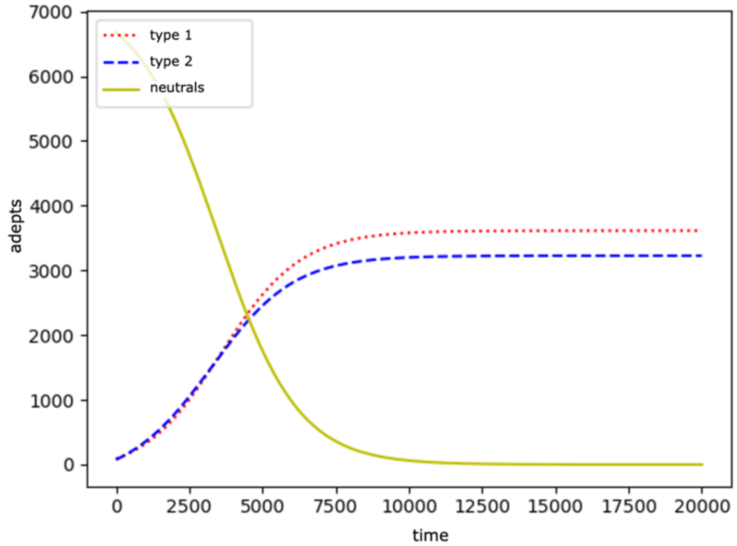

Fig. 8. Region 4

According to the absence of conflict, we obtained four independent models of information struggle (Fig. 5–8), which in turn affect the behavior of the model as a whole depending on its size, which can be seen in the graphs. Despite the slight advantage of I_2 in regions 1, 2, and 3, with the third region being the largest among all, it was still not enough to overcome the larger victory of I_1 in region 4. Therefore, overall, as we can see, the victory belongs to I_1, although this time, only within 1%.

This coincided with the result in section 1, but it is more of a coincidence because the behavior of the model is significantly different – there is a change of leadership and the final results differ by 1%. For clarity, if only the vector $N_2^{(0)} = (104, 24, 172, 26)$ is changed, I_2 victory can be obtained, with a larger permanent advantage without changing the leadership (Fig. 9).

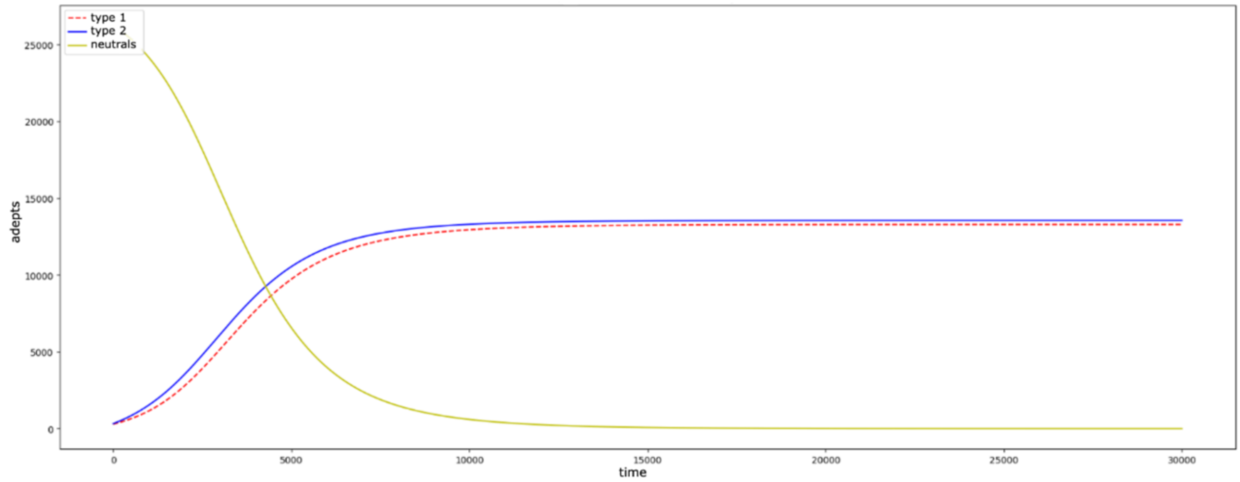

Fig. 9. General behavior of the model

However, this does not mean that the results of such a model cannot be predicted. For each region, it is enough to find the value of the win functions for each type of information and, taking into account the size of the corresponding region relative to the size of the entire community, calculate the corresponding total values.

5.2. The case with "natural conflict"

Now we take the coefficients in such a way that Adepts migrate to regions with a large number of Neutrals but few rivals in order to be able to recruit more individuals, and Neutrals migrate to regions with few Adepts in order to "have a calmer life." For example, $\alpha = -0.75, \beta = 0.5, \gamma = -0.8$

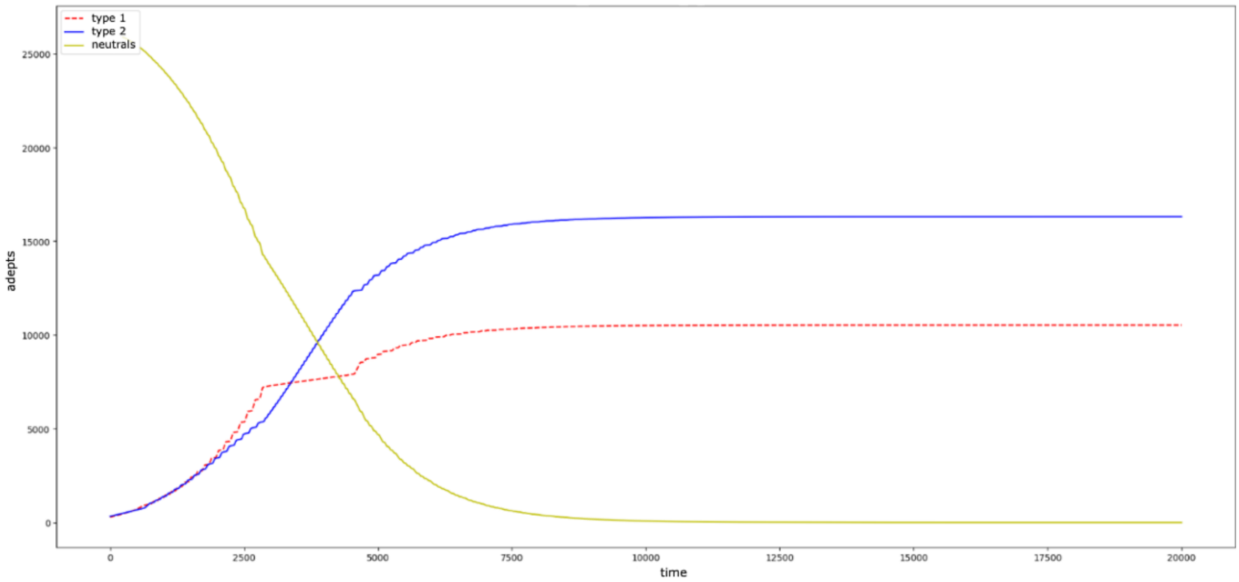

Fig. 10. The behavior of the model

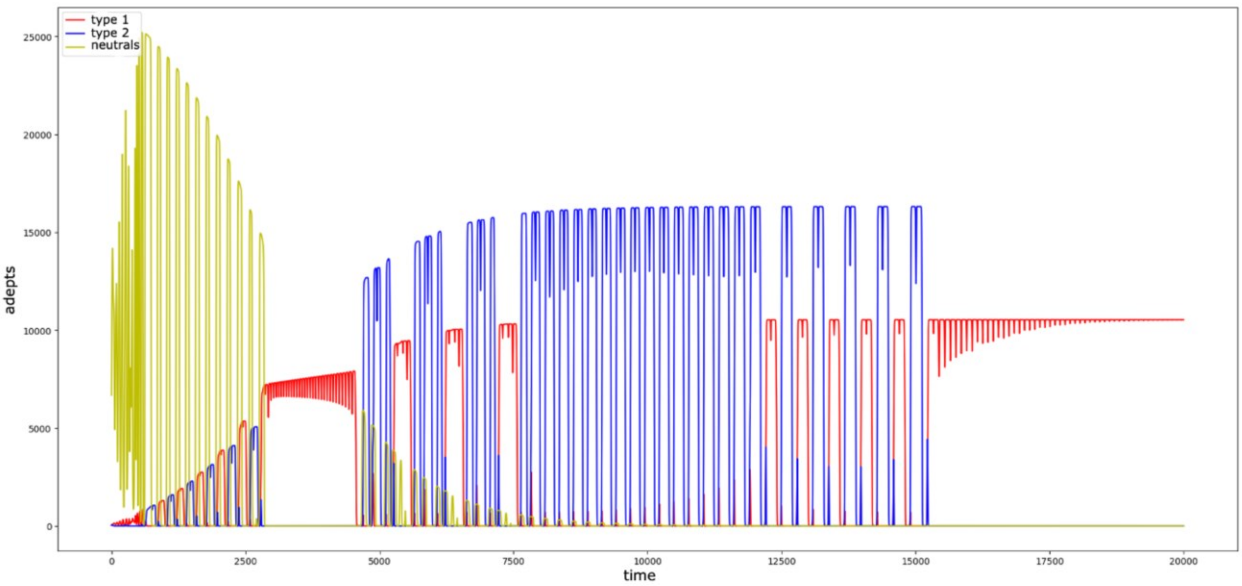

Fig. 11. Region 1

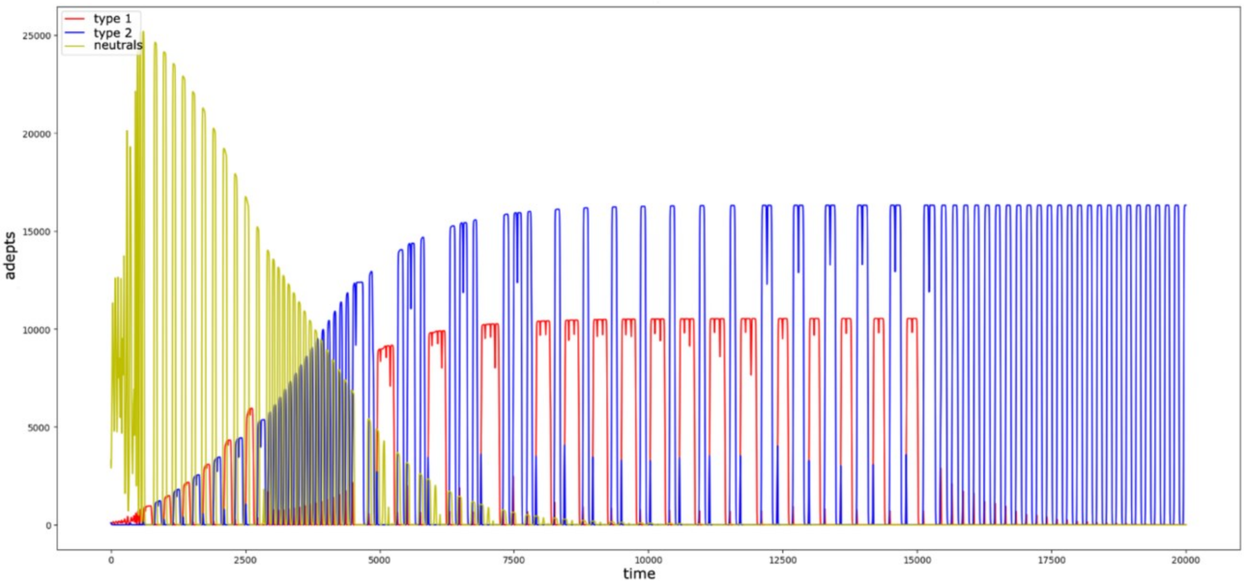

Fig. 12. Region 2

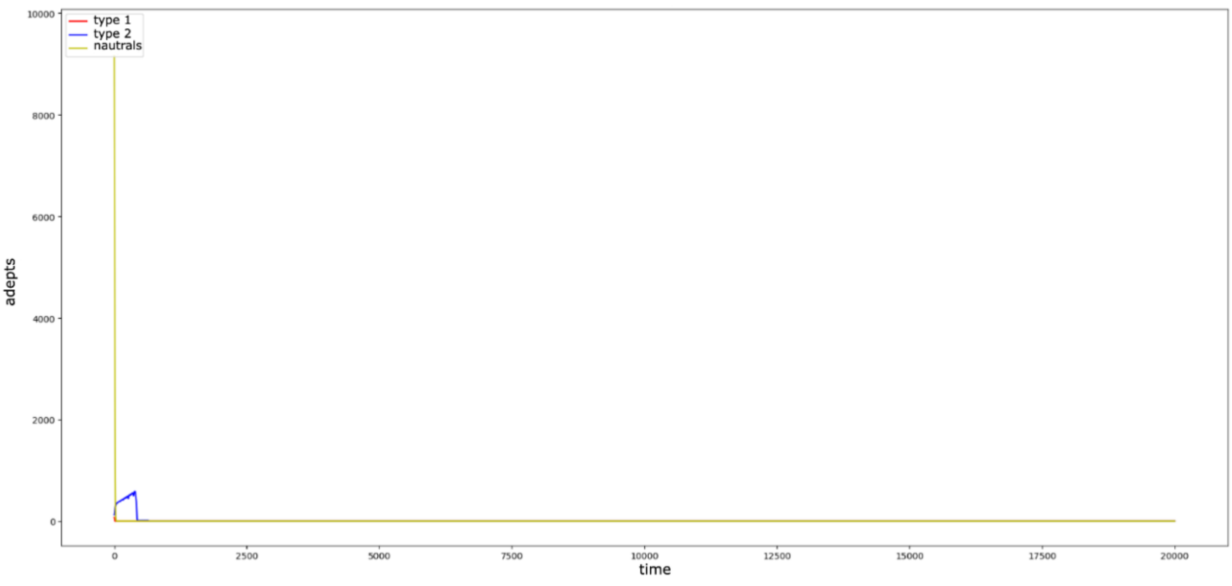

Fig. 13. Region 3

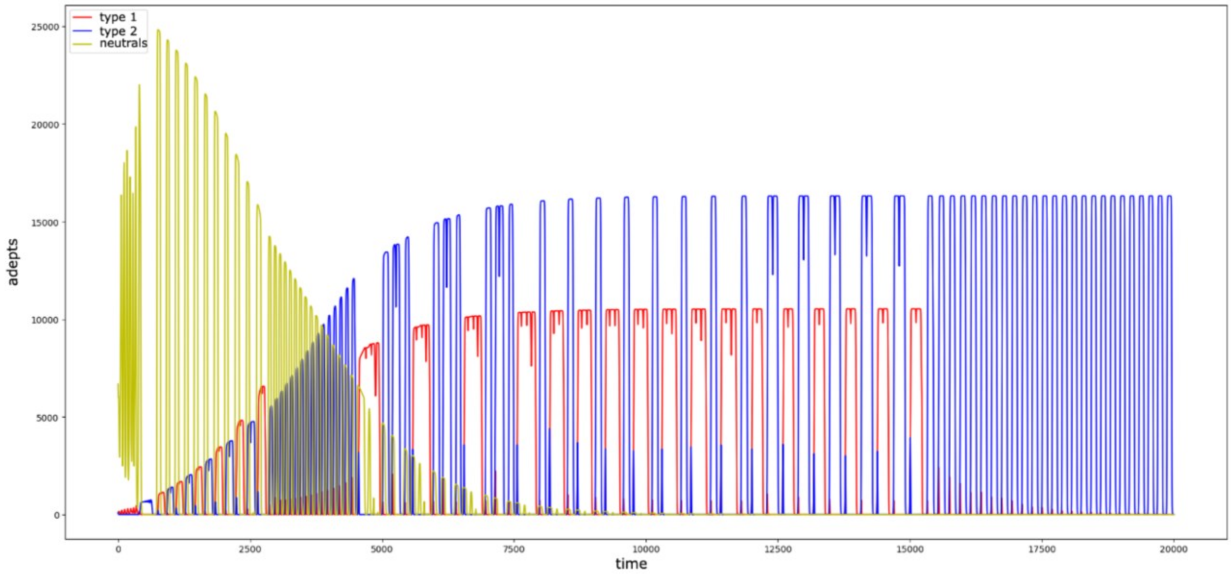

Fig. 14. Region 4

This time the results are much more interesting. From the general behavior of the model (Fig. 10), it can be seen that the second type of information won by an absolute margin. It can also be said that at the beginning I_1 still held the leadership for some time, until its growth rate decreased significantly, and in I_2, on the contrary, it increased strongly. And in general, in contrast to the model of information struggle, the growth rates here vary, which is clearly visible in the first third of the graph.

Now let us analyze the situation in each region in particular. First of all, it should be said that the third region almost immediately ceased to exist – all its resources were distributed among other regions at the very beginning, despite the fact that it is the largest among all.

In the other three regions, migration fluctuations occur throughout time, which only in the case of region 1 faded over time. In their behavior, four parallel stages for each region can be distinguished.

The first of them lasted from time 0 to $\approx$ 2900. During it, neutrals constantly migrate between these three regions, and at certain times they completely emigrate from each region, but return after some time (this is especially noticeable in region 2 and 4). At the same time, there is a rapid increase in the number of followers of the two types in each region.

The second stage ended around the time of 4500. During it, each region was dominated in the number of adherents of one information. What is more, all the neutrals emigrated from region 1 at this stage (which later returned), and I_1 adepts appeared instead. Although there was no competition for them here, the lack of neutrals also prevented them from spreading, which lasted until the end of the stage. This was the reason for the decline in growth, which in the future led to losses. In regions 2 and 4, the situation is completely opposite. Thanks to additional neutrals from region 1, I_2 adepts, despite little competition, were able to significantly expand their ranks, which explains the sharp increase in their pace.

The third stage is the longest, it ended around 15300. Here, all neutrals will already be recruited, and therefore the winner will be determined, which can be seen on the graph of the general behavior. However, within individual regions, everything is not so obvious. Adepts still migrate between regions, and the only thing that speaks of the superiority of I_2 adepts is the larger amplitude of oscillations in all regions and the almost complete displacement of I_1 in region 1 in the segment (7600;12100).

Only during the last stage, the behavior of the model become stable in all regions. In regions 2 and 4, the leadership is finally secured by the followers of I_2, and the migration fluctuations of I_1 fade away, going to zero. Region 1 is completely anchored by adepts I_1, whose quantity fluctuations also fade, but at the level of 10528, which is their final value. The oscillations of I_2 did not disappear, which can be explained by the presence of two regions for migration, where they dominate, as well as by different periods of oscillations that did not coincide.

The cases when the coefficients $\alpha > 0$ and $\beta \leq 0$ (as well as $\alpha = 0$ and $\beta > 0$) are essentially analogous since they mean that neutrals migrate to places where there are more adepts and adepts to where there are few neutrals. Although this does not correspond to natural conflicts, it fully supports migration. The sign of γ in a certain sense will also not change the model much, as it does not affect the interaction with neutrals. The behavior of the model will of course change, but the oscillatory migrations, like the example above, will remain.

5.3. The case $\boldsymbol{\alpha}, \boldsymbol{\gamma} > \mathbf{0}, \boldsymbol{\beta} \geq \mathbf{0}$

It can be interpreted as the migration of neutrals to where there are many adepts, and the adepts to where there are many neutrals, and the adepts themselves also migrate to where there are many competitors. Briefly, this behavior can be described as migration.

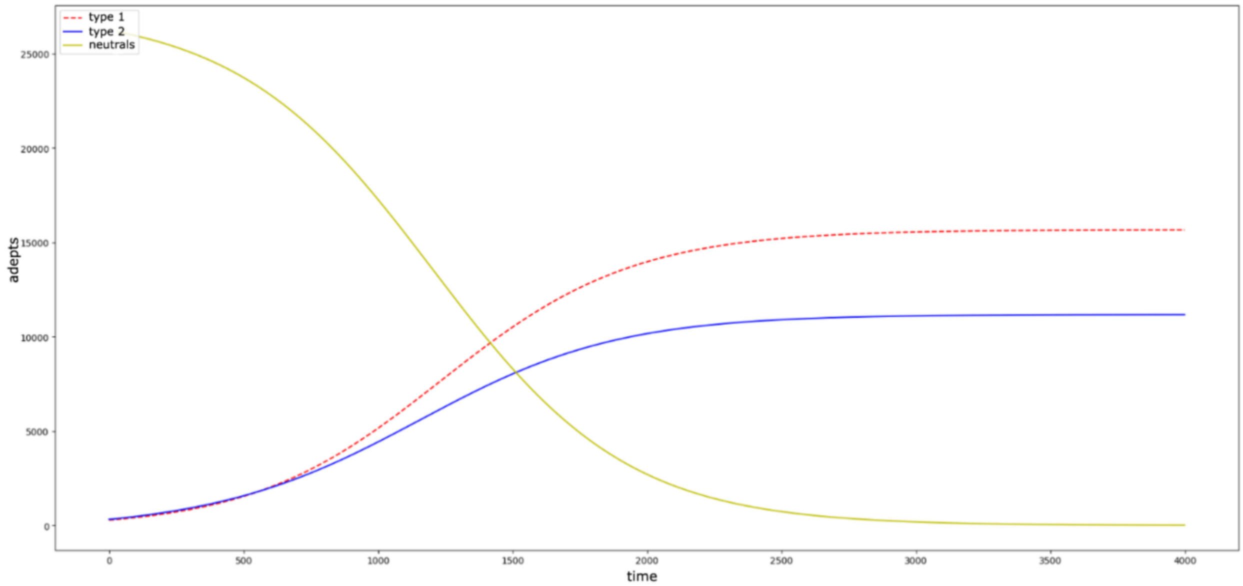

Fig. 15. The behavior of the model

It was established experimentally that for this model of information struggle, regardless of the values of the coefficients, if they are positive, the model behaves practically the same, namely:

The behavior in the regions resulted in the outflow of all resources to region 3 in a small number of cycles, which turned the model into a standard information struggle model.

There is nothing surprising in this, because, according to the parameters, all community members moved toward each other. Since the most significant region is the third, it became the goal of migration.

If $\alpha, \beta > 0$, and $\gamma \leq 0$, then the model behaves in the same way, except for the case when $-1 \leq \gamma < \Gamma, \Gamma \approx -0.5$ (the value of Γ was determined experimentally and requires further clarification and research). Then, the model again behaves relatively the same, regardless of the coefficients α and β. However, now due to the conflict between followers, some part of I_1, instead of migrating to region 3, migrated to the empty region 4, where they remained (information threat propagation model). This allowed I_2 to win in the main region 3, which still held practically the entire community. When increasing $|\gamma|$ the part of I_1 that did not migrate to region 3 also increases, while at $\gamma = -1$ the adepts completely separated in regions 3 and 4, thereby forming two models of information threat propagation.

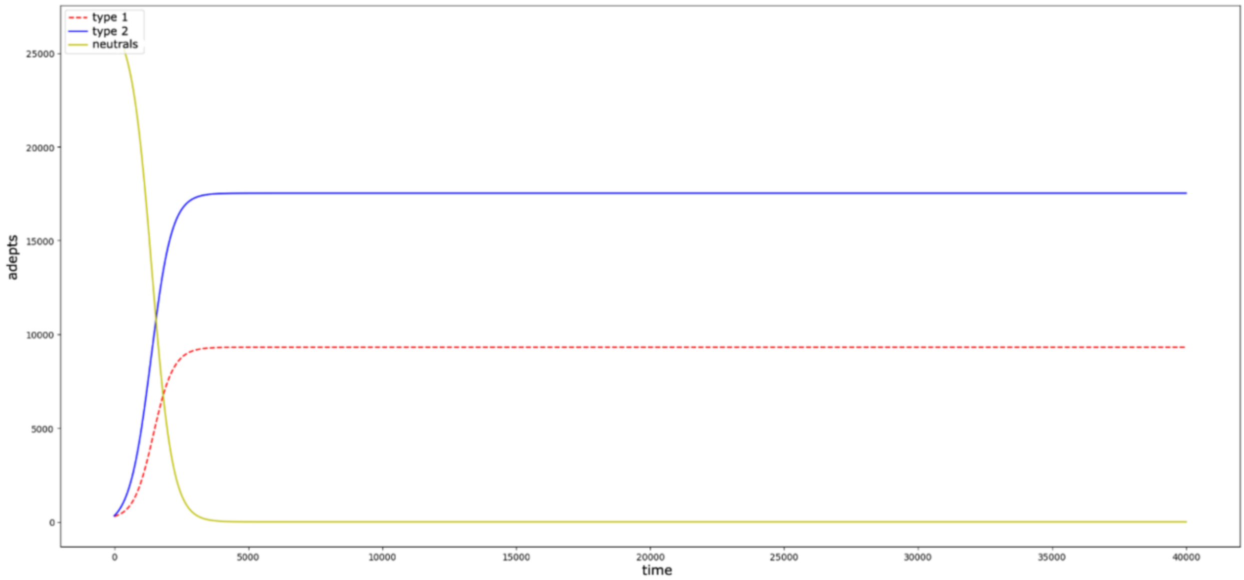

Fig. 16. The case when $\alpha, \beta > 0, \gamma \leq 0$

5.4. The case $\alpha \leq 0, \beta < 0$

The interpretation of such an example is as follows: neutrals migrate to places where there are few adepts, and adepts migrate to places where there are few neutrals.

This time, as a result of a series of experiments, it was established that regardless of the values of coefficients α, β, the behavior of the model, in general, does not change at all, but the behavior by regions changes significantly.

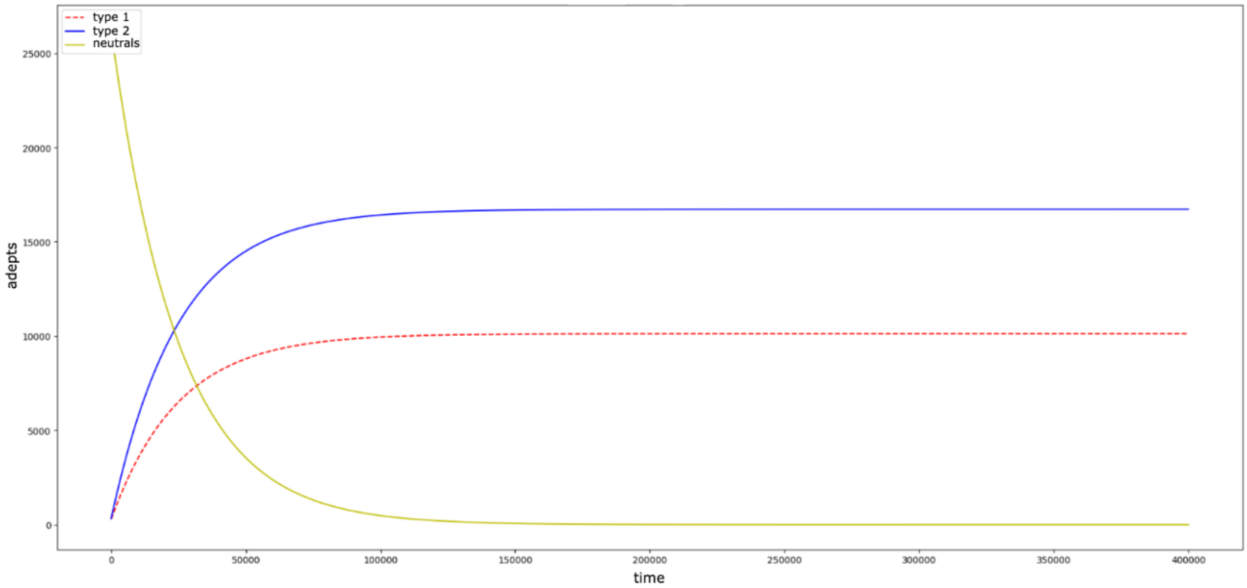

Fig. 17. The case when $\alpha \le 0, \beta < 0$

The situation is similar to example C, namely, depending on γ, the behavior of the model in the regions gradually changes from the information struggle model in region 2 at $\gamma = 1$ to the information threat spread model in regions 2 and 3 at $\gamma = -1$ (Fig. 17).

5.5. The case $\alpha = 0, \beta = 0, \gamma \neq 0$

In this case, a conflict only between followers of different types of information.

When $\gamma < 0$, adepts of different information migrate to rival-free regions, and due to the lack of migration among neutrals, such migration is reduced to a complete separation of adepts in regions where there are free members of the community who do not migrate anywhere. The behavior in each region is a model of information threat spreading: 1 (I_1), 2 (I_1), 3 (I_2), 4 (I_1). Meanwhile, the behavior in general also does not change significantly depending on the value of the coefficient.

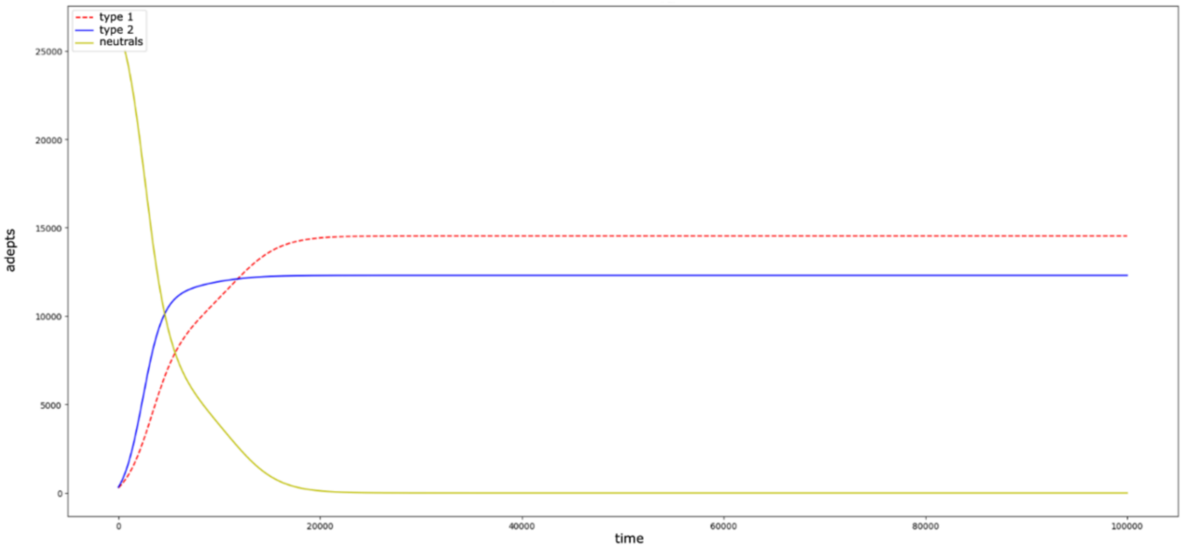

Fig. 18. The case when $\alpha = 0, \beta = 0, \gamma < 0$

When $\gamma > 0$, adepts migrate towards each other, and therefore all members of the community are concentrated in the largest region. Although there are still a large number of neutrals in other regions, under the influence of external channels of information dissemination, they also, albeit relatively slowly, become recruited, after which they migrate to meet other adepts in region 3. Depending on the value of the coefficient, the behavior of the model does not change in general and fully corresponds to the behavior in the third region - the information warfare model.

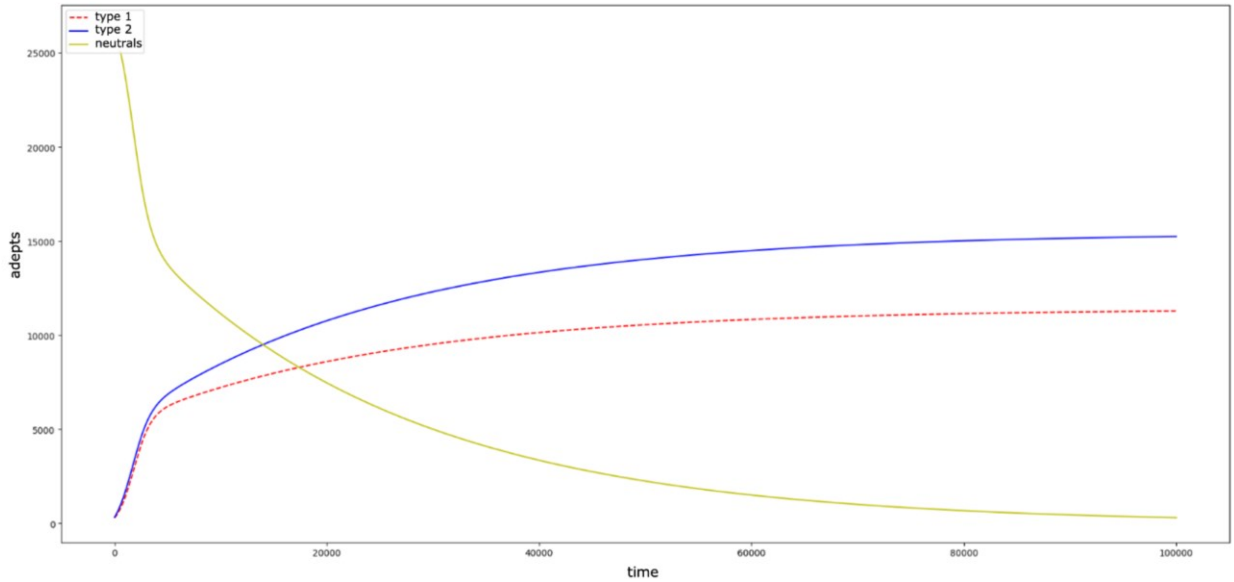

Fig. 19. The case when $\alpha = 0, \beta = 0, \gamma > 0$

6. Conclusions

Having studied the model of information struggle separately, it was found that the opposing parties have (including depending on the "capacity" of the social community) many opportunities to achieve victory. Depending on the coefficients of external and internal intensities, as well as, in a certain feature, the initial values, different scenarios of the model's behavior unfold: permanent leadership, leadership change, and parity. However, in each such situation, it is possible to predict the final results with sufficient accuracy using the win function.

The integration of internal conflict into the model brings significant and interesting changes in its behavior. First of all, it was found that the greatest influence is not the values of the interaction coefficients, but their signs, which determine the directions of migration. The division into regions also has a significant impact, and depending on the initial divisions, the language also changes.

In some cases, the internal conflict turns the model into a standard model of information struggle, such as with all positive coefficients of interaction. In such a situation, the model does not differ at all from the same one, but without division into regions and with the absence of conflict. Or, with appropriate coefficients, it is possible to separate rivals in separate regions, thereby reducing their behavior to a standard model of the spread of an information threat.

But the most interesting results were obtained when studying the behavior of the model with coefficients that describe natural conflict. It completely changes the behavior of the system. And as we have seen, these changes vary from a slowdown in the general process of "capturing" of the entire space to an increase in the behavior in general, and the behavior in the regions is characterized by constant migration fluctuations with stable and non-stable periods, different amplitudes.

It is obvious that when introducing a conflict, determine the final result, knowing only the starting conditions, if possible, then only in certain special cases. Predicting the behavior of the natural conflicts that are most important for research is impossible, and the only way to do this is through computer simulations using a sufficient number of iterations.

Therefore, in the presence of an internal migration conflict, the behavior of the information struggle model cannot be predicted without proper modeling. Even the behavior at $t \to \infty$ is not obvious – it can be both constant and fluctuating. Therefore, further research into this problem is extremely important.

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