A Modified Model for Effective Counteraction to Disinformation

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Introduction

This paper presents a new, modified mathematical and computational model for the effective counteraction of disinformation. Earlier studies [1] introduced models in which counteraction was carried out exclusively through information flows, whereby disinformation was exposed. Both disinformation flows and their exposing counterparts are assumed to influence public opinion, transforming individuals into adherents of one type of information or another.

During the spread of false and corrective information, society can be conventionally divided into several groups:

- the **risk group**, consisting of individuals who have not yet accepted either false or corrective information;
- the **adherent group**, comprising individuals who have adopted false information;
- the **immune group**, consisting of individuals who have accepted corrective information or rejected the false one.

When modeling the dynamics of disinformation counteraction, the primary focus lies on the size of these groups and the evolution of their proportions over time. This modeling framework is commonly referred to as the **compartmental approach**.

The objective of combating disinformation is to control the size of the adherent group. Individuals under the influence of false information are more likely to make inadequate decisions or engage in harmful actions detrimental to societal development. Accordingly, the smaller the adherent group, the lower the risk of social destabilization. For instance, during democratic elections, the likelihood of radical figures gaining power decreases as the adherent group diminishes.

In many countries, the fight against disinformation also occurs at the legislative level. For example, in Georgia, beginning in 2025, the so-called *"Law on the Criminalization of Disinformation"* has been reinforced. The dissemination of false information may entail administrative or criminal liability, while media outlets found guilty of spreading disinformation may face fines or revocation of broadcasting licenses. Thus, alongside corrective information flows, an additional lever in the struggle against disinformation has emerged. This new circumstance necessitates modifications in existing models of disinformation counteraction.

Main part

In this part of the work, the principles and methods of constructing a mathematical, computer model of the dissemination of false and revealing information will be considered. We will formulate the problem of optimal control of the fight against disinformation. We will conduct a computer experiment for various parameters of the model, analyze the results obtained and draw the appropriate conclusions.

Model construction

When building a mathematical, computer model for the dissemination of false and revealing information, we will adhere to the following assumptions. The process of disseminating information in a society with a constant number N will be observed at a time interval $[0;T]$. There are two sources of dissemination of information in the society: the source $Y5-DF$ at each moment of time $t\in[0;T]$ disseminates false information in the amount of: the source at each moment of time spreads false information in the amount $y_5(t)$, see Figure 1.

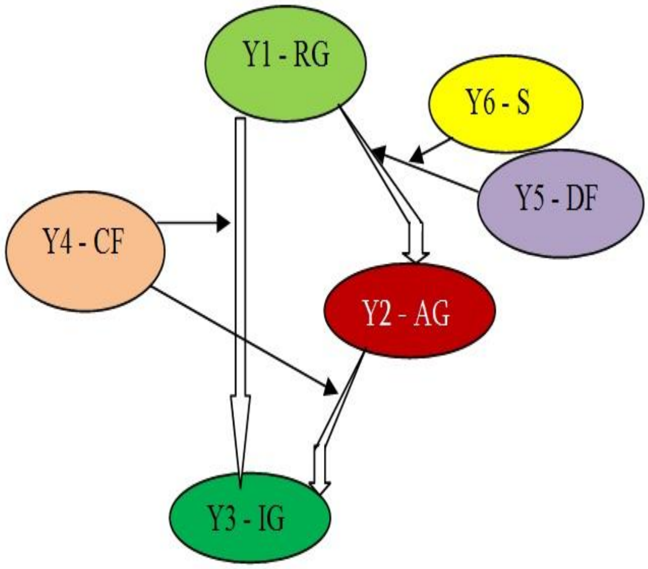

Figure 1. Scheme of information dissemination and stratification of society

And the source $Y4-CF$ at each moment in time $t \in [0;T]$ disseminates revealing information in the amount of $y_4(t)$. Society, as a result of the dissemination of false and revealing information, is divided into several groups: $Y1-RG$ the **Risk Group**, consisting at each moment of time $t \in [0;T]$ of $y_1(t)$ persons who have not yet accepted either false or revealing information; $Y2-AG$ the Adept Group - in the number $y_2(t)$ of persons who have accepted false information; $Y3-IG$ the **Immune Group** - in the number $y_3(t)$ of persons who have accepted revealing information or rejected false information for another reason. We will assume that a person who has once rejected false information does not become an adept of false information in the future.

We will write down the mathematical relationships of the rate of change of the number of each of the groups of society, as well as the rate of change of the flows of false and revealing information. We will describe in detail the rate of change of the number of members of the risk group, which will then be easily transferred to other groups - adepts and immunity. The number of members of the risk group decreases as a result of the influence of flows of false and revealing information, as well as as a result of interpersonal communication with members of the adept and immunity groups. Note that the number of the risk group cannot increase, while for other groups there is no such limitation.

The rate of decrease in risk group members depends on $\lambda(t)y_1(t)y_4(t)$, which means the impact of the flow of revealing information $y_4(t)$ on the Risk Group with a coefficient $\lambda(t)$. Note that according to the balance principle, the rate of change in the members of the immunity group increases by the same amount. The rate of decrease in risk group members also depends on $\kappa(t)y_2(t)y_5(t)$, which means the impact of the flow of false information $y_5(t)$ on the Risk Group with a coefficient $\kappa(t)$. The rate of decrease in risk group members also depends on interpersonal contacts with adept groups and with immunity and are respectively equal to: $-\alpha_1(t)y_1(t)y_2(t)$, $-\alpha_2(t)y_1(t)y_3(t)$. Where $\alpha_1(t)$, $\alpha_2(t)$ are the coefficients of effectiveness of interpersonal contacts of the noted groups. Thus, the rate of decrease in risk group members can be written as follows:

$$\frac{dy_1(t)}{dt} = -\lambda(t)y_4(t)y_1(t) - \kappa(t)y_5(t)y_1(x) - \alpha_1 y_1(t)y_2(t) - \alpha_2 y_1(t)y_3(t). \quad (1)$$

The rate of change in the number of groups of adherents and immunity is derived similarly, and for each of these groups we obtain ratios similar to (1). We will also assume that the speed of dissemination of false $y_5(t)$ and revealing $y_4(t)$ informations are oriented, respectively, to the number of risk groups and adherents, and is limited by the possibility of IT with the help of which sources distribute flows of their information. At the same time, various sanctions can be imposed on the dissemination of false information, which should be reflected in the model. Taking these considerations into account, we can create a mathematical model of the dissemination of false and revealing information in society in the form of a dynamic system of ordinary differential equations with variable coefficients:

$$\begin{cases} \frac{dy_1(t)}{dt} = -\lambda(t)y_4(t)y_1(t) - \kappa(t)y_5(t)y_1(x) - \alpha_1(t)y_1(t)y_2(t) - \alpha_2(t)y_1(t)y_3(t), \\ \frac{dy_2(t)}{dt} = \alpha_1(t)y_1(t)y_2(t) + \kappa(t)y_5(t)y_1(x) - \lambda_1(t)y_4(t)y_2(t) - \gamma(t)y_2(t) - \beta_1(t)y_2(t)y_3(t), \\ \frac{dy_3(t)}{dt} = \gamma(t)y_2(t) + \alpha_2(t)y_1(t)y_3(t) + \beta_1(t)y_2(t)y_3(t) + \lambda_1(t)y_4(t)y_2(t) + \lambda(t)y_4(t)y_1(t), \\ \frac{dy_4(t)}{dt} = \omega_1(t)y_2(t)\left(1 - {y_4(t)}/{M_1}\right), \\ \frac{dy_5(t)}{dt} = \omega_2(t)y_1(t)y_6(t)\left(1 - {y_5(t)}/{M_2}\right). \end{cases} \tag{2}$$

Where in (2) M_1 and M_2 are the values of the levels of those Internet Technologies, with the help of which the flows of revealing and false information are distributed respectively. The influence of the value of the authority's sanction $Y6-S$ in (2) is reflected in the fifth equation of the system in the form of a function $y_6(t)$, which can also take negative values, while the remaining coefficients are positive.

Problem formulation

For system (2), we define the initial conditions, thus obtaining the Cauchy problem for a dynamic system:

$$\begin{cases} y_1(0) = y_{10} > 0, y_2(0) = y_{20} > 0, y_3(0) = y_{30} \geq 0, \\ y_4(0) = y_{40}, \quad y_5(0) = y_{50}. \end{cases} \tag{3}$$

In system (2), we will search for unknown functions in the class of continuously differentiable functions on - $[0;T]$ - $C^1[0;T]$. Thus, for the Cauchy problem (2), (3), there is a unique solution. At the end of the time interval T, the value of the function $y_2(t)$ determines the number of adherents of disinformation at the end of the observed interval $y_2(T)$ and is an indicator of the effectiveness of the fight against disinformation. If the value $y_2(T)$ is greater than $0,05N$, then this may mean that by the elections scheduled for time T, people susceptible to false information can elect anti-state political parties to power. In many countries, the threshold for entry into parliament is 5% of voters. Thus, it is necessary to manage the fight against disinformation in such a way that the condition is met:

$$y_2(T) < 0,05N. \tag{4}$$

As shown in [1], for information and state security, it is necessary to control the number of adherents not only at the end of the time interval, but throughout the entire interval. Therefore, the boundary condition (4) should be replaced by the following conditions:

$$y_2(t) < 0,05N \qquad \forall t \in [0;T]. \tag{5}$$

Control of the system (2) means transferring the system from state (3) to state (5). In the proposed model, we have two control parameters, the first parameter we defined in earlier works [2] and it is the flow of revealing information - $y_4(t)$, the second control parameter arose as a result of legislative responsibility for disinformation and we will denote it by $y_6(t)$. For the control bet $(y_4(t), y_6(t))$, we will compose the so-called price $F\left(y_4(t), y_6(t)\right)$ for transferring the system from state (3) to state (5). Naturally, we need to look for a control pair $\left(y_4^*(t), y_6^*(t)\right)$ that has the lowest price - $F\left(y_4^*(t), y_6^*(t)\right)$. Thus, we formulated the problem of optimal control of combating disinformation under new conditions:

$$F\left(y_4(t), y_6(t)\right) \to inf, \quad y_4(t), y_6(t) \in C^1[0;T]. \tag{6}$$

subject to (3), (5) - we will call it "A task". Note that the problem of optimal control of combating disinformation is and (6), (3), (4) - we will call it "B task".

Computer experiment

We will conduct the computer experiment in the MatLab environment, and first of all we will be interested in the possibility of controllability in tasks A and B. By controllability of a dynamic system we will mean the existence of control , which transfers the system from state (3) to (5), or (4). During the calculation we will assume that the coefficients of system (2) are constant.

Let us have the following boundary conditions: : $T = 15$, $y_1(0) = 400$, $y_2(0) = 50$, $y_3(0) = 10$, $y_4(0) = 1$, $y_5(0) = 17$, $y_2(15) \le 460/20 = 23$. The coefficients of system (2) have the values: $\lambda = 0{,}01$; $\lambda_1 = 0{,}015$; $\kappa = 0{,}010$; $\alpha_1 = 0{,}003$; $\alpha_2 = 0{,}017$; $\beta_1 = 0{,}015$; $\gamma = 0{,}001$ $\omega_1 = 0{,}019$; $\omega_2 = 0{,}079$; $M_1 = 40$; $M_2 = 55$. And the control $y_6(t)$ has the following form:

$$y_6(t) = -pt^2 + 1, \quad p \ge 0. \tag{7}$$

If $p = 15$, then the computer experiment shows that task B is controllable, see Fig. 2.

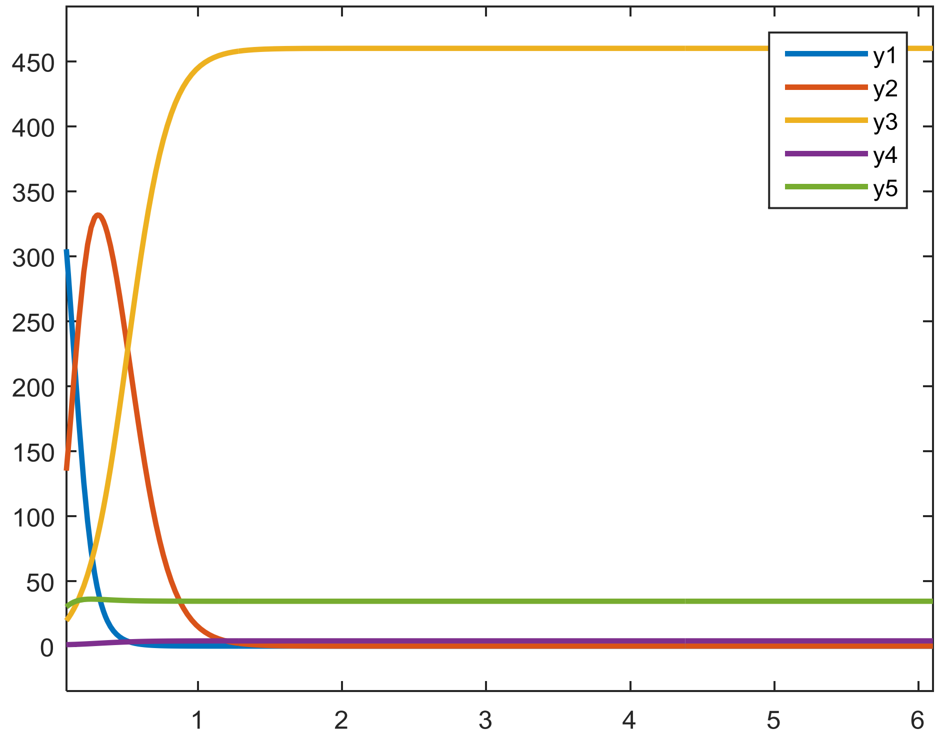

Fig. 2. In the control $y_6(t)$ parameter $p = 15$

Indeed, $y_2(0{,}94) < 23$, and condition (4) is satisfied when $N = 460$. However, for task B we have $y_2(0{,}9) > 23$, and therefore condition (5) is not satisfied - for task A controllability is not achieved. For task A controllability is not achieved if in the control parameter p is increased by an order of magnitude $p=115$. see Fig. 3.

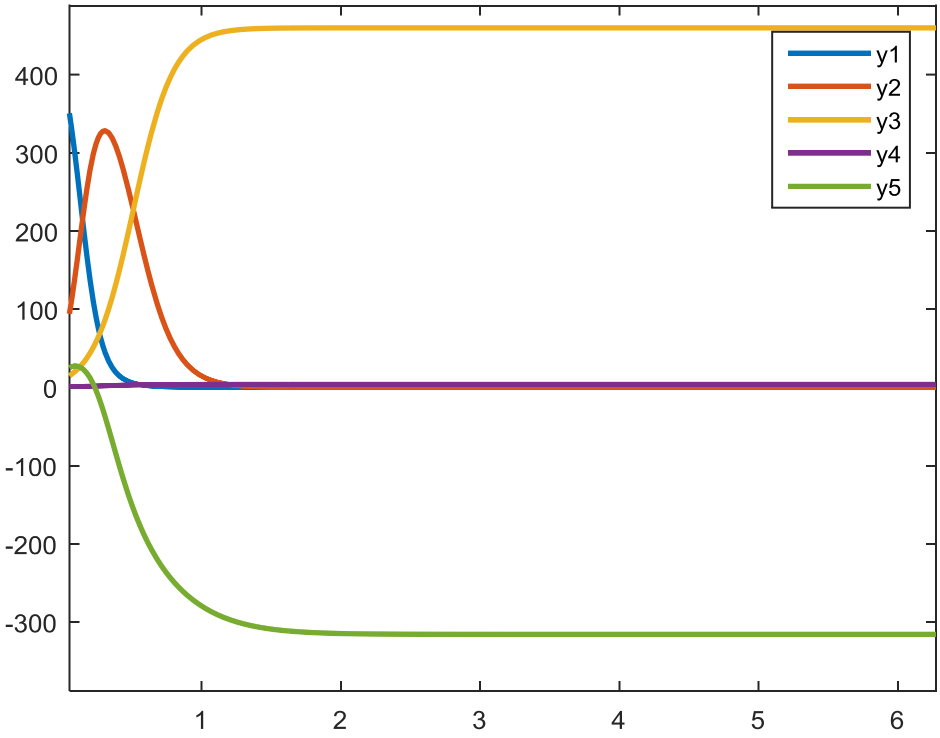

Fig. 3. In control $y_6(t)$ parameter $p=115$

For a computer experiment in the MatLab environment, the ode15s solver is used, the code listing is given below:

Listing

```
[X,Y]=ode15s(@adsys,[0 15],[400 50 10 1 17]);
plot(X,Y,'linewidth',2); legend('y1','y2','y3','y4','y5');


function dydx=adsys(x,y)
l=0.01; l1=0.015; k=0.010; a1=0.03; a2=0.017;
b=0.015;g=0.001;
o1=0.019;o2=0.79; m1=40; m2=55;p=15;
dydx=[-l*y(1).*y(4)-k*y(1).*y(5)-a1*y(1).*y(2)-a2*y(1).*y(3)
    a1*y(1).*y(2)+k*y(1).*y(5)-l1*y(2).*y(4)-g*y(2)-b*y(2).*y(3)
    g*y(2)+a2*y(1).*y(3)+b*y(2).*y(3)+l1*y(2).*y(4)+l*y(1).*y(4)
    o1*y(2).*(1-y(4)/m1)
    o2*(y(1).*(1-y(5)/m2)).*(-p*x.^2+1)];
end
```

Controllability for task A and B is achieved if the value of the parameter decreases by an order of magnitude - $\kappa=0,001$; - parameter of influence of disinformation on members of the risk group and the number of adherents is initially equal to 15. refer to Fig. 4.

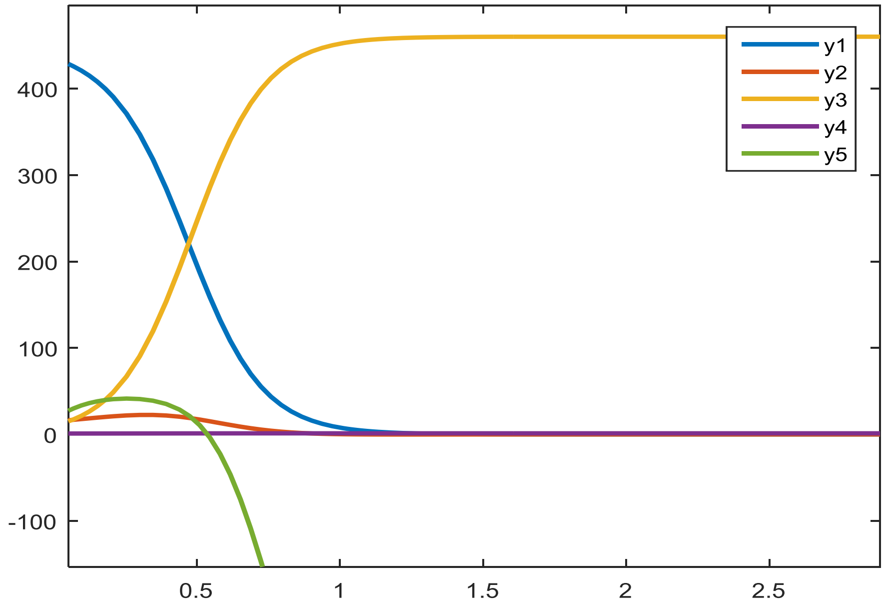

Fig. 4. Controllability for $\kappa = 0,001;$

If in a numerical experiment we increase by an order of magnitude the values of the parameter of interpersonal communication of groups of rysk and adepts $\alpha_1 = 0,03;$, then, as can be seen from the graph in Figure 5, controllability for task A is not achieved:

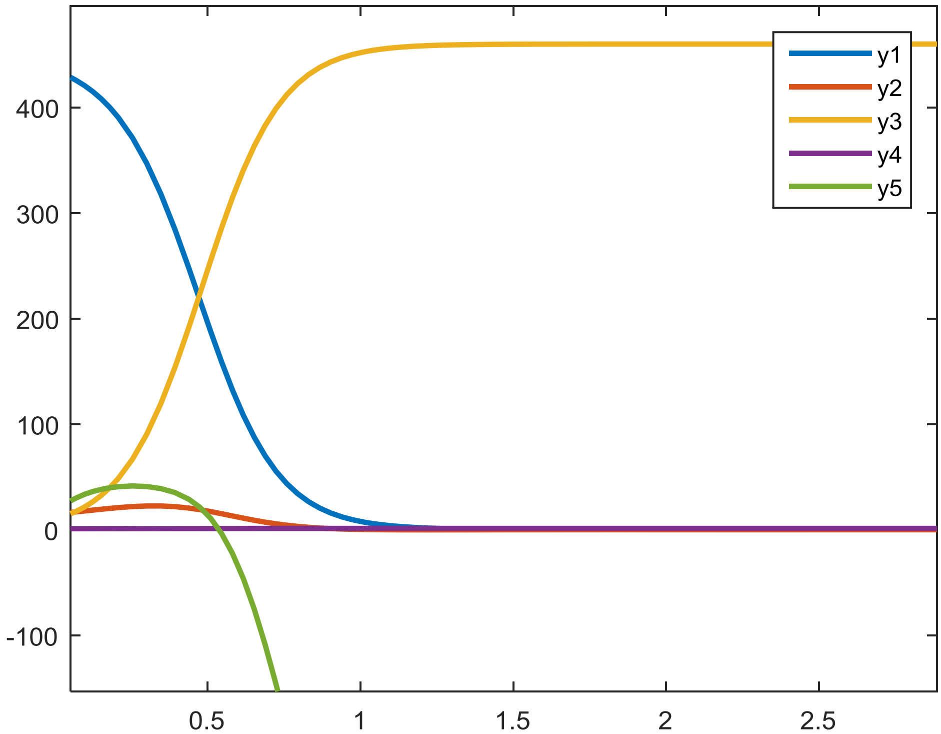

Fig. 5. Controllability for $\alpha_1 = 0,03;$

Conclusion.

Thus, a new mathematical model of dissemination of false and revealing information has been constructed, which takes into account the legislative possibilities of administrative and criminal liability for dissemination of false information. Two tasks of optimal management of combating disinformation have been set - tasks A and B. Using a computer experiment, the possibilities of controllability of tasks A and B have been identified. It has been established that sanctions for dissemination of false information, which are taken into account in the model, and their use as control parameters, make it easy to achieve controllability in Task B, while controllability of Task A may not be achieved. Controllability of Task A, and thus achievement of Information Security in society is achieved by complex control methods. When, in addition to sanction possibilities, the parameters of dissemination of revealing information, intergroup contacts are included in the control.

References

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