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A MATHEMATICAL MODEL OF INFORMATION CONFRONTATION: DISCRETE ADAPTIVE CONTROL OF THE SYSTEM

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Abstract. This article presents initial results of controlling a mathematical model of information confrontation, proposed by the authors in earlier works. The model is a system of ordinary differential equations with quadratic nonlinearity on the right side. The introduction defines the novelty of the approach and outlines the differences from previously used ones. Additionally, the substantive meaning of the variables and parameters of the system is described, and the stages of research on this model are briefly presented. In the parameter space, a component is established, by controlling which we obtain relations that determine the predictable behavior of the system trajectory from any initial point corresponding to the substantive meaning. In the main part of the work, an algorithm for constructing discrete adaptive control is proposed, which allows reducing the information confrontation to a scenario advantageous for one of the parties. The example shows the procedure for using the model and the algorithm for building the control step-by-step. The numerical solution of the system of differential equations was performed using the solve_ivp module for solving ordinary differential equations of the SciPy library of the Python programming language.

Keywords: mathematical model, information confrontation, information promotion, differential equation, adaptive control, numerical solution of differential equation system

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МАТЕМАТИЧЕСКАЯ МОДЕЛЬ ИНФОРМАЦИОННОГО ПРОТИВОБОРСТВА: ДИСКРЕТНОЕ АДАПТИВНОЕ УПРАВЛЕНИЕ СИСТЕМОЙ

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Аннотация. В статье представлены первые результаты управления математической моделью информационного противоборства, предложенной авторами в более ранних работах. Модель представляет собой систему обыкновенных дифференциальных уравнений с квадратичной нелинейностью в правой части. Во введении определена новизна подхода и его отличие от ранее использовавшихся. Также описан содержательный смысл переменных и параметров системы и кратко представлены этапы исследования данной модели. В пространстве параметров установлена компонента, управляя которой, можно получить соотношения, определяющие предсказуемое поведение траектории системы из любой начальной точки, соответствующей содержательному смыслу. В основной части работы предложен алгоритм построения дискретного адаптивного управления, который позволяет свести информационное противоборство к выгодному для одной из сторон сценарию. На примере показана процедура использования модели и алгоритма построения управления по шагам. Численное решение системы дифференциальных уравнений проводилось с использованием модуля solve_ivp для решения обыкновенных дифференциальных уравнений библиотеки SciPy языка программирования Python.

Ключевые слова: математическая модель, информационное противоборство, продвижение информации, дифференциальное уравнение, адаптивное управление, численное решение системы дифференциальных уравнений

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Introduction

Interest in modeling the process of promoting new information through the media is determined by the fact that this information can be used with equal success both to unite and stabilize society, and to divide and destabilize it. Success in promoting fundamentally new ideas into society largely depends on the positions of the main acting forces. On the one hand, influential media with the ability to shape public opinion, and, on the other hand, various subjects of society such as expert communities, executive authorities, political parties, public organizations have the ability to use another part of the media to present alternative point of view and «promotion» of their concepts within the society [1]. Here we are dealing with a certain information confrontation.

A number of noteworthy works are dedicated to modeling this process. In article [2] a detailed review of some of them was conducted. It was observed that they share a common approach to modeling the process of information confrontation. All models are described through characteristics of the population of various recipient groups, which, in one way or another, belong to one of the conflicting parties in the information space [3–10]. In the future, it is likely that confirmation of the adequacy of each of the obtained theoretical models by empirical data will be required, which will require the use of standard sociological tools in the form of a survey of a sample population, followed by the use of traditional statistical methods for parameter identification and data analysis.

However, researchers now have new tools for their investigative work, such as Data Science and Text Mining. New opportunities have also opened up. We have proposed a fundamentally different approach to analyzing the spread of new information through the media, which does not rely on sampling theory to study public opinion, but instead involves working with big data. Sociologists studying public opinion argue that the inherent characteristics of Big Data provide more effective forecasting capabilities than traditional methods [11, 12]. The absence of samples (n=All) and direct work with statistical populations or very large portions of them, data scalability, constant automated collection of data in archives and the ability to quickly process them ultimately lead to high reliability and demand for "real-time" forecasting. Therefore, in our opinion, it is more relevant in modern conditions to conduct research not by measuring the number of people taking a position "for" or "against" a certain point of view, but by analyzing the volume and intensity of information received in the media aimed at achieving goals that do not coincide in interests.

This work serves as a continuation of a systematic study of the mathematical model of information confrontation that accompanies the stages of emergence and dissemination of information through the media, aimed at promoting new views or concepts in society.

$$\begin{aligned}
&\frac{dN}{dt} = \beta N - \gamma AN,\\
&\frac{dC}{dt} = \alpha AN - \mu\left(C - C_*\right),\\
&\frac{dA}{dt} = \rho C - \eta\gamma AN - \lambda A,\\
&\frac{di}{dt} = \sigma N - \omega i.
\end{aligned} \qquad (1)$$

The phase variables of this system are quantities identified as factors that describe the most general patterns of confrontation in the dissemination of information through the media:

$N(t)$ is a quantitative characteristic of the volume of news information (quantity of articles, messages of various types, units ($quan\{N\}$)), corresponding to the promotion in the information space of new – reformist, sometimes overly radical – views;

$C(t)$ is the number of entities in the structure of the information space with special resources, the purpose of which is to preserve previously accepted concepts in society (ideological or technological, units ($quan\{C\}$));

$A(t)$ is a quantitative characteristic of the volume of conservative information (quantity of articles, messages of various types, units ($quan\{A\}$)), opposed to the spread of radical views in the information space;

$i(t)$ is an indicator of the share of the population that is loyal to new ideas appearing in the media: $i = 1 - \frac{I^*}{I}$, where $I(\%)$ corresponds to the full acceptance of prevailing conditions in society before the start of observations; $I^*(\%)$ is the corresponding characteristic of the acceptance of these positions when disseminating new perspectives in the media. The content characteristics of the model parameters are presented in Table 1.

In the system (1), the variable $i(t)$ appears only in the last equation, so the study was carried out for a lower-dimensional system, rewritten in a more convenient for study form:

Table 1

Content characteristics of the model parameters [18]

$\beta \geq 0$	An indicator characterizing the intensity of spread of new information through the media $\left(\frac{1}{t}\right)$.
$\gamma \geq 0$	An indicator characterizing the possibility of neutralizing the effect of information that appears after presenting an alternative opinion $\left(\frac{1}{quan\{A\}\cdot t}\right)$. Inversely proportional to the amount of information A per unit of time.
$\alpha \geq 0$	An indicator characterizing the intensity of societal reaction to the confrontation of alternative points of views $\left(\frac{quan\{C\}}{quan\{A\}\cdot quan\{N\}\cdot t}\right)$. Average number of conservative media outlets, which contrasts with the volume of new trend messages over a given period of time.
$\mu > 0$	A coefficient inversely proportional to the time of operation of additionally created agencies of information $\left(\frac{1}{t}\right)$.
C_*	An amount of information resource for daily support of the currently prevalent concept of society.
$\rho \geq 0$	An average speed of news appearance from one information entity $C\left(\frac{quan\{A\}}{quan\{C\}\cdot t}\right)$.
$\eta \geq 0$	An average percentage of information A directed to neutralize the effect of messages N.
$\lambda > 0$	A coefficient inversely proportional to the time of forgetting information $A\left(\frac{1}{t}\right)$.
$\sigma \geq 0$	An indicator characterizing the pace of adopting new idea that have appeared in the media $\left(\frac{1}{quan\{N\}\cdot t}\right)$.
$\omega \geq 0$	An indicator characterizing the return, due to the inertia of thinking, to the existing concept of society $\left(\frac{1}{t}\right)$.

$$\begin{aligned} \frac{dC}{dt} &= \alpha AN - \mu\left(C - C_*\right), \\ \frac{dA}{dt} &= \rho C - \left(\lambda + \eta\gamma N\right)A, \\ \frac{dN}{dt} &= \left(\beta - \gamma A\right)N, \end{aligned} \tag{2}$$

with initial conditions, due to its autonomy:

$$C(0) = C_0 \geq 0,\ \ A(0) = A_0 \geq 0,\ \ N(0) = N_0 \geq 0. \tag{3}$$

Articles [13–15] describe in detail the stages and results of the theoretical part of the modeling process [16, 17]. Therefore, in the work [13], the mathematical formulation of the problem was carried out and a mathematical model was built. The correctness of the model was checked, including dimensional control, nature of dependencies, physical relevance and existence of solutions. Several important regions were identified in the parameter space of the model, where the dynamic system exhibits different

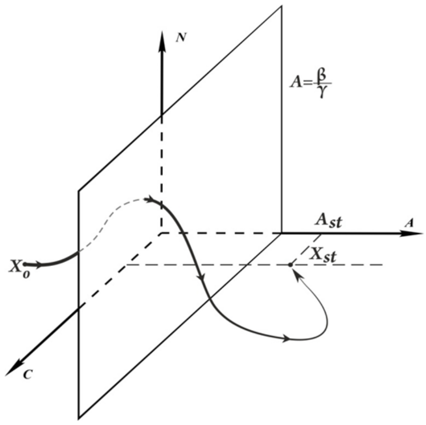

Fig. 1. Qualitative behavior of the trajectory
of the system (2) from the point $X_0 = \left(C_0; A_0; N_0\right) = \left(10;12;68\right)$ [18]

topological properties. In articles [13, 14], based on the Lyapunov function method, qualitative analysis of solution behavior was conducted in each parameter region, and global phase portraits of trajectories of the proposed dynamic system were built. A detailed interpretation of the model under study was carried out in [15].

In article [18], the first step of the next stage of modeling was taken – checking the adequacy of the model or assessing the correspondence of the model to real data. The model performed well in the analysis of one of the high-profile information events at the beginning of 2022 – media coverage of the attempted coup in Kazakhstan. A comparison of the qualitative behavior of the integral curves of the model and graphs presented by the media monitoring system during the period of observation of the event showed good consistency. Fig. 1 shows the calculated trajectory of the system (2), which accurately reflects the real situation. As can be seen from the figure, an increase in the values of $N\left(t\right)$ and $A\left(t\right)$ of the trajectory $X\left(t\right) = \left(C\left(t\right), A\left(t\right), N\left(t\right)\right)$ after the start of movement (the point $X_0 = \left(C_0; A_0; N_0\right) = \left(10;12;68\right)$ was obtained using the media monitoring system) indicates a confrontation between different points of view when covering the event. The result shows the outcome of this confrontation (Fig. 1).

$X_{st} = \left(C_{st}, A_{st}, N_{st}\right) = \left(C_*, \frac{\rho C_*}{\lambda}, 0\right)$ is an asymptotically stable stationary solution interpreted as a state of society in which a certain concept dominates, and to support it, an administrative resource in the amount of C_* uses a sufficient amount of information, from its point of view, in the media $\frac{\rho C_*}{\lambda}$.

This step is important in the sense that a "sample" of the trajectory of the system (2–3) was obtained, which can be interpreted as a successful outcome of information confrontation for those entities defending the accepted societal views against unwanted perspectives covered in the media.

However, such a trajectory behavior determined by a set of parameters corresponds to only one of the many scenarios described in [15], namely: when performing inequalities

$$\begin{cases} \gamma\rho C_* > \lambda\beta \\ \rho\alpha > \mu\eta\gamma + \beta\eta\gamma \end{cases} \tag{4}$$

any trajectory of the system (2) starting from an arbitrary point in the set $R_+^3 = \left\{\left(C, A, N\right) \in R^3 : C \geq 0, A \geq 0, N \geq 0\right\}$ tends towards an asymptotically stable stationary solution $X_{st} = \left(C_{st}, A_{st}, N_{st}\right) = \left(C_*, \frac{\rho C_*}{\lambda}, 0\right)$.

In other cases, depending on the parameter relations and initial conditions trajectory behavior may significantly differ [15] from that presented in the figure. In such cases, phase portraits describing the system's dynamics will have different topological properties [19]. Thus, for a favorable – in terms of substantive meaning – outcome of the confrontation, interested parties need to manage the dynamic model of the ongoing process. This, for example, will help approximate the trajectory of the system to a "sample" and, therefore, from the perspective of the conservatively inclined part of society, ensure the desired outcome in the struggle against undesirable information in the media space. *This work specifically considers this case.*

The system (2) describing the process of information confrontation can be considered as controlled, understanding control as an influence on certain parameters of the system. In this case, based on the system of inequalities (4), it is logical to assume that the parameter ρ of the system (2) is most suitable for control. Indeed, by increasing it, considering the substantive meaning and leaving other parameters unchanged, under certain conditions, it is possible to achieve the satisfaction of inequalities (4).

Formulation of the problem

Let us assume that active discussions of an extraordinary event have started on media channels capable of influencing certain values established in society. Within the framework of the research object, it is necessary to formulate a thesis that describes the existing societal concept. In accordance with this, all information supporting this thesis will reflect the quantitative characteristic of the phase variable $A(t)$. We will refer to it as information with a positive or optimistic tone. Consequently, any information contradicting this thesis in any form will reflect the quantitative characteristic of the phase variable $N(t)$ and have a negative or pessimistic tone. Informational bodies publishing information with a positive tone, collectively, will reflect the quantitative characteristic of the phase variable $C(t)$. Thus, by using electronic media monitoring systems and the algorithm described in [18], initial conditions (3) of the system (2) describing the movement of information flows directed at covering this event can be determined.

Let us denote the beginning of the trajectory movement of the system at $t = 0$ as a point $X^* = (C^*; A^*; N^*)$ in the phase space of the system (2). For example, when covering the aforementioned attempted coup in Kazakhstan by the media, the value of the variable N^* can be determined based on information about the initial occurrences of negative reports (see Table 2).

Table 2

Number of negative messages by day during January [18]

Day of the month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Number of negative messages	1	0	1	0	68	327	177	127	94	362	151	110	91	85	58	41
Day of the month	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Number of negative messages	50	52	38	37	14	13	8	20	6	14	96	47	14	17	8	

According to these data, $N^* = 68$. The value of $A^* = 12$ was taken as the arithmetic mean of the number of positive reports several days before the appearance of negative reports (see Table 3).

To determine the initial condition $C^* = 10$, it was necessary to use data on permanent sources providing the media with positive information about the CSTO for the entire previous year (see Fig. 2).

Let us assume that after some time values of all parameters of this system have been determined.

It should be noted that when analyzing the media coverage of the events in Kazakhstan, the possible range of variation for each parameter was determined to calculate their values. Subsequently, using the well-known Monte Carlo method, a set of parameters was chosen that provided the most acceptable deviation of the calculated trajectory from the actual monitoring data. The complete algorithm for parameter calculation is planned to be described in the next paper. For example, when estimating the parameter

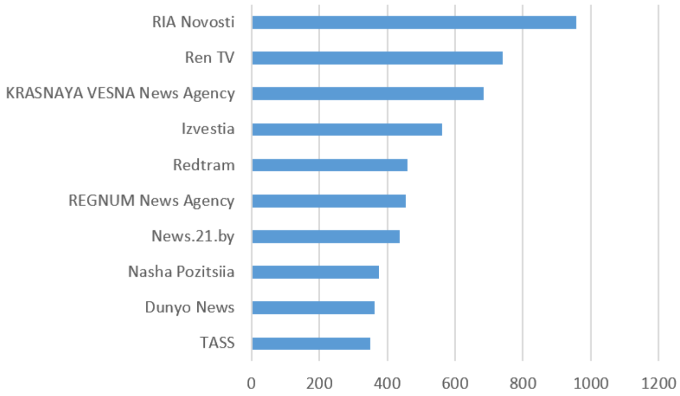

Fig. 2. Top sources with positive information *A* about the CSTO for 2021 [18]

β, a differential equation $\frac{dN}{dt} = \beta N$ was used, derived from system (2) after removing the nonlinear term from the right side of the corresponding equation. Taking into account the initial conditions, its solution has the form: $N(t) = 68\exp(\beta t)$. According to Table 2, *N*(1) = 327, which is possible with β_{min} = 1,57. Further comparison of parameter values showed that β = 1.9 most accurately reflects the situation. A similar analysis allowed estimation of the parameters ρ and α. To estimate the parameter λ, data from experiments on memory studies were used, based on which the Ebbinghaus's forgetting curve was constructed[1], showing how the level of retention of learned information logarithmically decreases over time. The range of γ and η values was determined according to the monitoring system data based on text sentiment analysis. In particular, using the built-in rating scale, the analysis showed that the messages *A* were mostly aimed not at neutralizing the messages *N*, but rather at proving the usefulness of the creation of the CSTO and the need to use this organization's armed forces in these conditions. Finally, the value of μ was determined based on data about the emergence of information from new sources that had not previously shown interest in the topic.

Table 3

Number of positive messages by day during January [18]

Day of the month	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
Number of negative messages	22	5	8	13	272	3653	2896	1933	1474	2797	1871	1282	1499	817	718	481
Day of the month	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	
Number of negative messages	349	360	500	206	141	158	94	92	123	82	91	120	158	51	90	

If the value of the parameter is such that the system of inequalities (4) is satisfied, then a successful outcome of information confrontation for the control authorities is guaranteed. Otherwise, as shown in [15], scenarios of information confrontation may have different results. Therefore, for a successful outcome, it is necessary to adjust the parameter ρ through adaptive control $u = u(t)$ [20]. Let a control

[1] Averell, L., Heathcote, A. The shape of the forgetting curve and the fate of memories. *Journal of Mathematical Psychology*, 2011, Vol. 55, no. 1, pp. 25–35.

function $u = u(t)$ be given characterizing the level of increase in the parameter ρ of system (2) and satisfying constraints:

$$0 \le u(t) \le u_{\max}, \quad 0 \le t \le T, \tag{5}$$

where $u_{\max} \ge 0$ is the maximum degree of increase in the average speed of news appearance from one information entity ρ (according to the semantic characteristic of the parameter), T is the time interval of observing the information event. Let us assume that under the control influence, the parameter ρ of the system (2) can change from the value ρ_0 to $\rho_{\max} = \rho_0(1+u_{\max})$, where ρ_0 is the value of the parameter set during identification, taking into account media monitoring at the initial stage, and $u_{\max}$ is such an arbitrary value that the parameter ratios satisfy the inequalities (4).

The system (2) with the introduced values will have the following form:

$$\begin{aligned} \frac{dC}{dt} &= \alpha AN - \mu(C - C_*), \\ \frac{dA}{dt} &= \rho(1+u)C - (\lambda + \eta\gamma N)A, \\ \frac{dN}{dt} &= (\beta - \gamma A)N. \end{aligned} \tag{6}$$

The control objective may be to ensure that the trajectory behavior of the system is close to a "sample", i.e., asymptotically approaching the point $X = \left(C_*, \frac{\rho C_*}{\lambda}, 0\right)$. In the proposed model, such an outcome is primarily associated with the dynamics of the volume of news information $N(t)$. Therefore, as a "sample" for control, we find the solution of the system (6) at $u \equiv u_{\max}$ with the initial condition $C(0) = C^*,\ A(0) = A^*,\ N(0) = N^*$ and extract the integral curve $N^*(t)$. To define the control criterion for the considered process on the interval [0; T], we set up a uniform grid:

$$\Xi = \left\{ t_i : t_i = i\Delta t,\ i = \overline{1, M};\ \Delta t = \frac{T}{M} \right\}, \tag{7}$$

on which we fix the volume of news information corresponding to the "sample":

$$N^*(t_i) = N_i^*, \quad i = \overline{1, M}. \tag{8}$$

We will consider that for the solution of system (6), the condition:

$$\left| N(u(t), t_1) - N_i^* \right| < \varepsilon, \quad i \in I = \{r, \ldots, M\}, \quad 1 < k \le r < M, \tag{9}$$

with a sufficiently small ε corresponds to achieving a successful outcome of information confrontation. Here, k: t_{k-1} is the moment of the start of control, before which it is assumed to identify the parameters of the system (2) and, accordingly, (6). We will call the condition (9) the criterion of discrete adaptive control for the system (6).

Thus, the stated problem involves constructing the control $u(t),\ t \in [0; T]$, that ensures the fulfillment of condition (9) for the solution of the system (6) with initial conditions (3) under the constraint (5).

Algorithm for adaptive control construction

Let us define the set U as follows. Let us assume that on each interval $[t_{i-1}; t_i),\ i = \overline{1, M}$ the function $u(t)$ is constant and satisfies the inequalities (5). Thus, the control function will be chosen from the set of piecewise-constant functions on the interval [0; T]. Consequently,

$$U = \left\{ u(t) : u(t) = u_{i-1} \in [0; u_{\max}],\ t \in [t_{i-1}; t_i),\ i = \overline{1, M},\ u(T) = u_{M-1} \right\}.$$

We will assume that under every admissible control $u = u(t)$ the system (6) with initial conditions (3) has a unique solution $X(u(t), t) = (C(u(t), t), A(u(t), t), N(u(t), t)),\ u(t) \in U,$ defined for all $t \in [0; T]$.

According to the criterion (9) it is required to construct control $u(t) \in U$ satisfying the condition:

$$\left| N(u_{i-1}, t_i) - N_i^* \right| < \varepsilon, \quad i \in I.$$

To construct the control function $u(t) \in U$, the following algorithm is proposed:

Reduce the problem solution to the sequential integration of the system (6) on intervals $t \in [t_{i-1}; t_i]$, $i = \overline{1, M}$. Thus, only phase variables are unknown functions at each fixed value u_{i-1}. Their right end values are the initial conditions for the next time interval. Let us assume that $u_0 = u_1 = ... = u_{k-2} = 0$. On intervals $[t_{i-1}; t_i],\ i \geq k,$ denote

$$\Psi(u_{i-1}) = N(u_{i-1}, t_i) - N_i^*,$$

where $N(u_{i-1}, t_i)$ is the value of the function $N(u(t), t)$ at the point t_i for a fixed u_{i-1}. The set (8) is defined in such a way that $N_i^* < N(0, t_i),\ i \in I,$ i.e., $\Psi(0) > 0,\ i \in I$. The following options are possible:

- If $N_i^* \leq N(u_{\max}, t_i) < N(0, t_i),\ i \in I,$ then fix $u_{i-1} = u_{\max}$;
- If $N(u_{\max}, t_i) < N_i^* < N(0, t_i),\ i \in I,$ then to find u_{i-1} as solving the nonlinear equation

$$\Psi(u_{i-1}) = 0,\ u_{i-1} \in [0; u_{\max}]. \tag{10}$$

Due to the continuous dependence of the system (2) on parameters and the fact that $\Psi(0) > 0$, and $\Psi(u_{\max}) < 0$, the bisection method, for example, can be applied to solve equation (10).

Thus, it seems possible to determine all continuous components of the control function $u(t)$ and, consequently, solve the stated problem. Then the control function can be represented as follows:

$$u(t) = u_0 + \sum_{k=1}^{M-1} \theta(t - t_{k-1})(u_k - u_{k-1}), \tag{11}$$

where $\theta(t)$ is the Heaviside's function, defined by the formula

$$\theta(t) = \begin{cases} 1, & t \geq 0, \\ 0, & t < 0. \end{cases}$$

Numerical solution of the adaptive control problem

Numerical integration of the system (6) was performed using the solve_ivp module of the SciPy library in the Python programming language. The solve_ivp module provides a powerful tool for solving systems of differential equations in modeling and researching various processes [21].

As part of the SciPy library, the solve_ivp module seamlessly integrates with other modules and tools, such as NumPy and Matplotlib, offering a choice of several numerical methods for solving complex ODE systems [22]. One notable feature of the solve_ivp function is that it returns an array of numerical solution values at each point from the time array [23].

a) b)

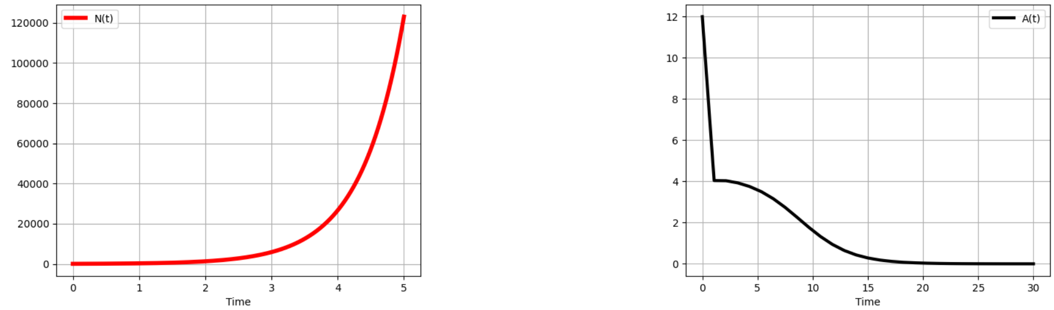

Fig. 3. Integral curves a) $N(t)$, and b) $A(t)$ of the system (2) with initial conditions $C(0) = 10$, $A(0) = 12$, $N(0) = 68$ and parameter values $\beta = 1{,}9$; $\gamma = 0{,}1$; $\alpha = 0{,}09$; $C_* = 10$; $\mu = 0{,}3$; $\rho = 5$; $\eta = 2{,}54$; $\lambda = 1/3$

To build adaptive control let us consider the situation described in [18]. When imitating different scenarios, it was noticed that numerical integration of the system (2) with initial conditions $C(0)=10$, $A(0)=12$, $N(0)=68$ and parameter values

$$\beta = 1{,}9;\ \gamma = 0{,}1;\ \alpha = 0{,}09;\ C_* = 10;\ \mu = 0{,}3;\ \rho = 5;\ \eta = 2{,}54;\ \lambda = 1/3, \qquad (12)$$

which are located outside near the boundary of the domain (4), the behavior of the system's solution changes abruptly.

The dynamics ofw variables $N(t)$ and $A(t)$ in this case have the following representation (Fig. 3).

For these parameter values the value of the phase variable is $N(t) \to +\infty$ when $t \to +\infty$. From a substantive point of view, this corresponds to a situation where the appearance in the media of information aimed at changing society's concept can find support and lead to an undesirable threat to the traditional system of views for government structures. In this regard, it is necessary to determine methods of control that allow changing the dynamics of factors $N(t)$ and $A(t)$, which are indicators of society's reaction to emerging information in the media.

Let us construct the control function $u(t)$ that allows changing the behavior of the integral curve $N(t)$ so that $N(u(t),t) \to 0$ for $t \to +\infty$.

Let us assume that by the time $t = 3$, all the parameters of the system (2) with the values (12) have been determined.

The parameter set (12) does not satisfy the conditions (4). As $\rho = \rho_0 = 5$, we can determine, for example, $u_{max} = 0{,}2418$ from which $\rho_{max} = \rho_0(1+u_{max}) = 5(1+0{,}2418) = 6{,}209$. This means an increase of the average speed of news appearance from one information body by almost 25%.

At the value of the parameter $\rho = \rho_{max}$ the conditions (4) are fulfilled, and the integral curve $N(t)$ corresponding to this value can be defined as "sample" integral curve.

The graph of this curve is presented in Fig. 4.

Now, let $\Delta t = 1$, $M = 30$ in (7) (this corresponds to the segment of observation of an information event in [18]), and $k = 4$ in (9). The integration results show that before the control begins the values of the integral curves $N(t)$ at $\rho = \rho_0 = 5$ (Fig. 3) and the "sample" integral curve $N^*(t)$ at $\rho = \rho_{max} = 6{,}209$ (Fig. 4) differ more and more over time (Fig. 5).

The volume of news information corresponding to the «sample» integral curve $N^*(t)$ from Fig. 5 is presented in Table 4.

Having this data, we can apply an algorithm for building adaptive control.

If $k = 4$, then $u_0 = u_1 = u_2 = 0$. To find u_3, we find the integral curve $N(u_{max}, t_4)$ of the system (6) on the segment $[t_3; t_4] = [3; 4]$, having previously defined $N(0, t_3) = 1080.38$ as the initial condition. We

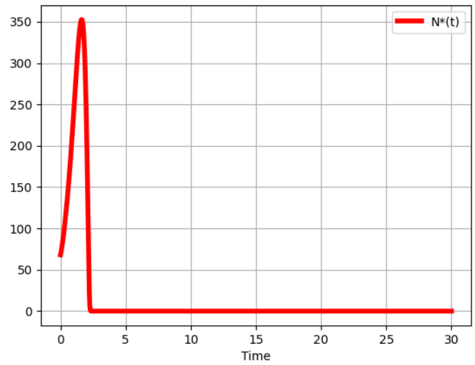

Fig. 4. Integral curve $N^*(t)$ of the system (2) with initial conditions $C(0) = 10$, $A(0) = 12$, $N(0) = 68$ and parameter values $\beta = 1{,}9$; $\gamma = 0{,}1$; $\alpha = 0{,}09$; $C_* = 10$; $\mu = 0{,}3$; $\rho = 6{,}209$; $\eta = 2{,}54$; $\lambda = 1/3$

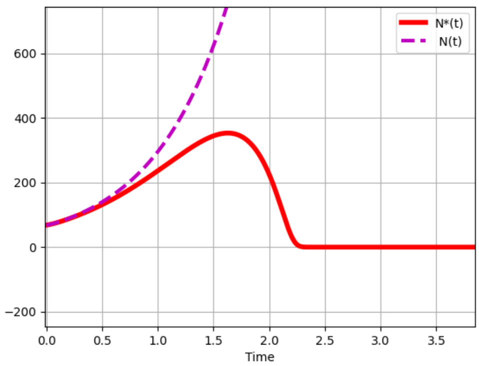

Fig. 5. Integral curves $N(t)$ and $N^*(t)$ before control at time $t_1 = 3$

have $N(u_{\max}, t_4) = 233.85 > N_4^* \approx 0,$ so we fix $u_3 = u_{\max}$ on $[t_3; t_4] = [3; 4]$. Next, to find u_4, we find the integral curve of the system (6) on the segment $[t_4; t_5] = [4; 5]$, taking = 233.85 as the initial condition. We have $N(u_{\max}, t_5) = 0 \geq N_5^* = 0,$ so we fix $u_4 = u_{\max}$ on $[t_4; t_5] = [4; 5]$. Etc.

Table 4

Number of negative messages $N^*(t)$

t	0	1	2	3	4	5	6	9	12	15	18	...	30
$N^*(t)$	68	235.135	228.409	2E-10	2E-10	0	0	0	0	0	0	0	0

Thus, the control function $u(t)$ (Fig. 6) and its corresponding integral curve $N(u(t), t)$ which gradually approaches the «sample» curve $N^*(t)$ over time (Fig. 7) were obtained through adaptive control.

Table 5 shows the values of $|N(u(t), t) - N^*(t)|$ at points on the grid (7). This corresponds to the satisfaction of the adaptive control criterion (9) for the system (6).

Conclusion

This article presents an algorithm for constructing adaptive control of a system of differential equations, presented as a mathematical model of information confrontation. The feature of this model is that

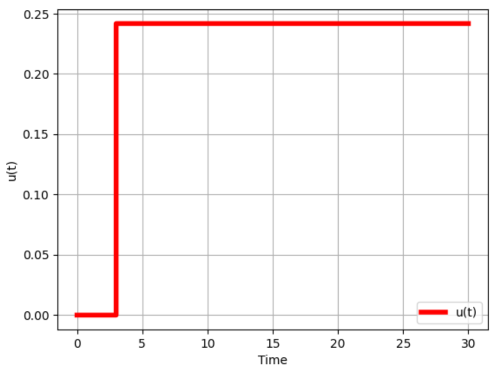

Fig. 6. Control function $u(t)$ during adaptive control from time $t_1 = 3$

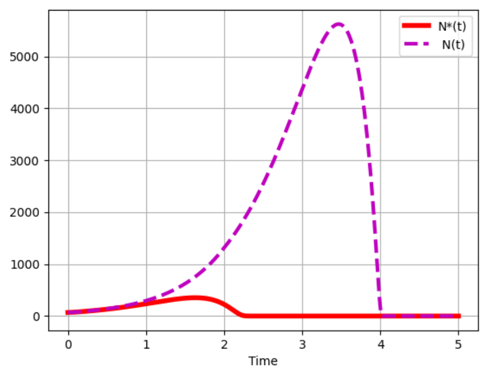

Fig. 7. Integral curves $N(u(t), t)$ and $N^*(t)$ after the start of the control

the subject of modeling is the quantity of information with competing orientations, in contrast to the generally accepted approach that defines the quantity of individuals holding opposing views on some information issue.

Table 5

Values of $\left|N(u(t),t) - N^*(t)\right|$ for checking the adaptive control criterion

t	0	1	2	3	4	5	6	9	12	15	18	...	30
$\left\|N(u(t),t) - N^*(t)\right\|$	0	59.149	1080.38	4359.1	233.85	0	0	0	0	0	0	0	0

The modern level of technical equipment, such as media monitoring systems and Text Mining, provides the ability to estimate continuously the quality and speed of information flows in real time. These flows, in one way or another, influence the introduction of new (possibly hostile) ideas into public consciousness.

The proposed new approach to modeling allows, in real time, to firstly identify critical situations that could potentially lead to an uncontrolled scenario in the information space. Secondly, it provides the ability to influence the outcome of the confrontation by managing certain parameters (e.g., content, volume, intensity).

In this article, a situation was simulated using a set of parameters determined by Monte Carlo method, where the media disseminates information that could lead to an unfavorable shift in public opinion for government structures.

In the model, this situation is reflected by an uncontrolled growth of one of the components of the system's trajectory, indicating the complete dominance of an antagonistic concept. This necessitated the construction of the control function, which particularly changes the dynamics of the phase variables of the system.

When solving this problem, the following results were obtained:

- For the initial state, obtained from the electronic media monitoring system, the concept of “sample” system trajectory was defined, which moves from the initial point to an asymptotically stable equilibrium of the system. This is only possible, if certain relations are met for the system parameters.
- In the system's parameter space, a component was identified as most suitable for control, allowing the trajectory to be directed towards the “sample” mode.
- A step-by-step algorithm for constructing adaptive system control was proposed, ensuring minimal deviation of the trajectory from the “sample” path after a finite number of steps.
- The proposed algorithm was implemented for numerical integration of the system using the solve_ivp module from the SciPy library in Python language.

Substantively, the situation described in the work led to the conclusion that it is necessary to increase the average intensity of news releases by news agencies. By increasing the intensity to the calculated level, there is a real chance to eliminate the adverse effects of an information attack on society.

Thus, the theoretical feasibility of influencing the confrontation between interested parties in promoting their interests through the media has been obtained and justified.

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