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ON A HYBRID METHOD FOR MODELING INFORMATION DISSEMINATION PROCESSES BASED ON AUTOMATA AND DIFFUSION MODELS

Ivohin E. V. – Dr. Sc., Professor, Professor of the Department of Intelectual Program Systems, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine. ROR: https://ror.org/02aaqv166. ORCID: https://orcid.org/0000-0002-5826-7408.

Adzhubey L. T. – PhD, Associate Professor, Associate Professor of the Department of Computational Mathematics, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine. ROR: https://ror.org/02aaqv166. ORCID: https://orcid.org/ 0000-0002-8487-0884.

Naumenko Yu. O. – PhD, Associate Professor of the Department of Automation and Information Technology, Kyiv National University of Construction and Architecture, Kyiv, Ukraine. ROR: https://ror.org/02qp15436. ORCID: https://orcid. org/0009-0003-6411-455X.

Rets V. O. – Post-graduate student of the Department of System Analysis and Decision Support Theory, Taras Shevchenko National University of Kyiv, Kyiv, Ukraine. ROR: https://ror.org/02aaqv166. ORCID: https://orcid. org/0009-0007-8632-7010.

ABSTRACT

Context. The modern information society, with its rapidly expanding means of information exchange and globalized data, offers the opportunity to study information dissemination, investigate its impact, and create information security systems. Mathematical modeling methods are widely used in the development of information dissemination systems and technologies. Thermal, diffusion, and mechanical processes – that is, processes occurring in a continuous medium – are considered fundamental. Among the various modeling approaches, equations of mathematical physics, which formalize the fundamental laws of substance transfer, are often used.

Objective. The aim of this paper is to develop a comprehensive, formalized approach to numerically modeling the dynamics of information dissemination processes in social networks based on the principles of cellular automata and diffusion models. The subject of the study is the analysis of the dynamics of the level of information generated based on the internal behavior of each network cell, assuming that its initial state is formed as a result of the influence of certain processes outside the information communities.

Method. This paper proposes a hybrid approach to modeling information dissemination processes based on cellular automata, which observes the internal and external dynamics of individual cells. The state change of the automata model is described by a specified transition function and rules for generating output signals, while a diffusion approach based on heat conduction principles is used to formalize internal changes in the cell's state. Computational experiments were conducted to model the dynamics of information dissemination processes, taking into account various types of external influences from others, and calculations of information dissemination dynamics indicators in social network communities are presented.

Results. The proposed hybrid model allows us to describe and analyze information dissemination processes within a social group, which is formed, for example, from social network subscribers. The group is divided into subgroups that are relatively homogeneous in terms of specific indicators in the form of online communities.

Information processes were modeled taking into account various external influences from surrounding environments (using von Neumann and Moore neighborhoods as examples) with explicitly defined transition and exit functions. Internal information dissemination processes in specific cells were formalized using scalar heat equations. Numerical calculations of information dissemination dynamics in each community and the group as a whole were obtained, and a solution to information content problems (participants' attitudes toward a specific problem) in subgroups was proposed based on determining the locations of centers of influence.

Conclusions. This article examines the application of cellular automata principles to modeling the dynamics of information dissemination processes. A new approach is proposed that, in addition to the automata model, considers the internal behavior of each cell, assuming that its initial state is formed as a result of certain intracellular processes at each time interval. In other words, a hybrid version of a cellular automaton for observing the internal and external dynamics of individual cells is considered, whereby the change in the states of the automaton model is described by a given transition function with certain rules for generating output signals, and a "mechanistic" approach based on the principles of thermal conductivity is used to formalize internal changes in the state of the cell.

KEYWORDS: modeling, information dissemination processes, diffusion models, cellular automata, hybrid approach, social networks.

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ABBREVIATIONS

CA is a cellular automata.

NOMENCLATURE

k is a time interval number;

T is a system uptime;

t_k is a k-th moment in time;

$x(t_k)$ are input signals;

$y(t_k)$ are output signals;

$z(t_k)$ are transition signals;

$F(z,x)$ is a transition function;

$G(z,x)$ is an output function;

Z is a set of system states;

$u(x,y,t)$ is a level of awareness function;

q_0 is a normalized source intensity;

α is an information diffusion coefficient;

δ is a Dirac delta-function;

Ω is a region that models a fragment of a social network;

$X(x)$ is a separation function on variable x;

$Y(y)$ is a separation function on variable y;

λ is an eigenvalue of the Laplace operator;

λ_{xm} is an eigenvalue of the function $X_m(x)$;

λ_{yn} is an eigenvalue of the function $Y_n(y)$;

X_m is an eigenfunction of Sturm-Liouville problem for the function $X(x)$;

Y_n is an eigenfunction of Sturm-Liouville problem for the function $Y(y)$;

$\phi_{mn}(\cdot)$ is an eigenfunction of two-dimensional problem;

$a_{mn}(\cdot)$ is a coefficient of the Green's function term;

$G(\cdot)$ is a Green function;

$H(t)$ is a Heaviside function;

ε_m is a constant;

π is a constant;

T_1 is a set heating temperature;

$t_{\max}$ is a set heating time.

INTRODUCTION

The environment of the modern information society in the conditions of rapid growth of information exchange means and the associated globalization of data provides an opportunity to study the problems of information dissemination, research its impacts, and create information security systems.

Mathematical modeling methods are widely used in the development of information dissemination systems and technologies [1]. Thermal, diffusion or mechanical processes, i.e. processes occurring in a continuous medium, are considered basic. Among the various approaches to modeling, mathematical physics equations are often used, which are a formalization of the fundamental laws of matter transport. Models are written in the form of partial differential equations of parabolic or hyperbolic type [2].

At the same time, the use of such models for the formalization of social and information processes does not allow us to confidently speak about the adequacy of the results obtained on the basis of the proposed ("mechanistic") approach to the dynamics of real processes [3]. This is primarily due to the need to take into account the discreteness of the environments in which processes operate, as well as the complexity of using special discrete methods, the use of which in modeling is based on the assumption that the behavior of the described processes is determined by local interactions of the elements involved in the processes.

The object of study is a information dissemination process in communities of social nets.

The subject of study is hybrid metod development for modeling the information dissemination processes based on automata and diffusion models.

The purpose of the work is to develop comprehensive formalized approach of numerical modeling the dynamics of information dissemination processes in social nets based on the using of operation principles cellular automata works and diffusion models. The study aimes to analyse information level dynamics which is formed on internal behavior of each considering net cell, provided that its initial state is formed as a result of the influence of some processes outside the information communities.

1 PROBLEM STATEMENT

Let us consider one of the modeling methods based on the cellular automata (CA) system [4]. A cellular automata system is a discrete dynamical system that describes the interaction of spatial elements (cells). Each cell functions according to rules that resemble the laws of operation of an abstract cellular automata [4], i.e. each new state of a cell at an arbitrary moment in time is determined by its previous state and, as a rule, the state of neighboring cells. It can be assumed that each discrete cell (automata) is connected by its inputs to the outputs of neighboring cells, and, conversely, the output channels of each cell are inputs for the surrounding cells.

Typical CA systems are characterized by the following general properties:

– the space of states is discrete and finite;

– changes in the states of all cells of the system occur simultaneously;

– a specific cell is only affected by neighboring cells.

The latter property emphasizes that the behavior of a CA system is completely determined by the interaction of its elements..

Considering the functioning of individual cells in terms of the theory of finite automata, it should be noted that:

1. Each cell represents an object whose functioning occurs at a discrete time $t_0 \le t_1 \le \dots$, $t_k \in [0,T]$, $k = 0,1,2,\dots$, T – system uptime;

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2. At any given time t_k, $k = 0,1,2,...$, a cell can be in one of the discrete states $z(t_k)$, $k = 0,1,2,...$, from a given set Z;

3. The cell can be affected by input signals $x(t_k)$, $k = 0,1,2,...$, as a result, we obtain a model of cell functioning with a one-step transition function

$$z(t_{k+1}) = F(z(t_k), x(t_k)) \quad (1)$$

and a cell output signals model $y(t_k)$, $k = 0,1,2,...$,

$$y(t_{k+1}) = G(z(t_k), x(t_k)). \quad (2)$$

It is assumed that the time count for all cells occurs synchronously, and the cell reaction is completed simultaneously within the same time interval $[t_k, t_{k+1}]$, $k = 0,1,2,...$, that is, each cell of the process being modeled is a synchronous automata, for which a general methodology for modeling the transport processes of various substances has been developed [5].

Thus, the model space the model (discrete in its nature) space of a real process consists of a certain set of cells, the functioning of which determines the dynamics of the overall system. However, Instead of analyzing the interaction of individual cells, we will investigate the internal behavior of each cell, assuming that its initial state is formed as a result of some internal processes that occur continuously at each interval $[t_k, t_{k+1}]$, $k = 0,1,2,...$. As a result of such formalization, the CA system, which is defined to describe the process in the form of sequences $z(t_k)$, $y(t_k)$, $k = 0,1,2,...$, is supplemented by models of the internal dynamics of each cell. We have a hybrid version of a cellular automata, the dynamics of whose behavior in the form of a set of rules (functions) for the transition of cells from one state to another (1) and the formation of output signals (2) is additionally described by nested models that formalize internal changes in cells.

We note that such processes are observed in the social, informational, and various technological spheres, when formal modeling of behavior based on the functioning of a set of homogeneous cells requires taking into account the effects of internal changes in cell states during the corresponding time intervals $[t_k, t_{k+1}]$, $k = 0,1,2,...$. The final state of such changes must be limited to possible state variants from the set Z, which is ensured by imposing special boundary requirements on the dynamics of the internal processes of each cell.

In this case, it is possible to consider separate conditions for the outputs or states of each cell, which allows for interesting tasks of studying and describing the functioning of the processes under study.

2 REVIEW OF LITERATURE

Among the known cellular automata models of dynamics, it is necessary to mention models in the form of hybrid automata, in which the description of processes in the general system and in each individual cell occurs on the basis of various dynamic relationships, taking into account the constraints that determine the switching of the content of the process behavior [6].

A typical approach to modeling the functioning of a cell system requires determining the parameters of the influence of the neighborhoods of each cell (in the form of von Neumann neighborhoods [7], Moore neighborhoods [7], etc.) and specifying the explicit form of the functions and , for a formal description of the states of the cells and their mutual influence on them, which is determined by the laws of the process being modeled.

Despite the existing difficulties in the choice of states and some idealization of the methodology for modeling real processes based on cellular automata models, this approach continues to be successfully used in studies of the dynamics of propagation and spreading processes (especially heat transfer and diffusion).

Among such methods and approaches, one can mention agent systems [8–11], the use of cellular structures [12], diffusion-limited aggregation methods [13], mixed-type tools [14], and others [15]. It should be noted that the aforementioned approaches are quite successful in solving specific applied problems [16, 17].

3 MATERIALS AND METHODS

Let us take detailed look one of such cellular automata models for formalizing the process of information dissemination (penetration). Let us define a certain social group (for example, a set of participants in a social network), in which it is possible to distinguish separate communities (subgroups) according to specific characteristics. The power of communities can be different, but provided that there is no external interaction between them, this is considered insignificant. Each individual community (cell) is an element of the system that describes the dynamics of the general set based on a given set of rules for changing states.

Let us assume that within the subgroup there is a discussion of some information innovation, as a result of which an attitude towards it is formed. Each situation in individual subgroups (in the form of a certain state of the cell of the CA system) is a consequence of the dissemination of information and is characterized by the corresponding level of information saturation (agreement), the final indicator of which should be described by elements of a discrete set of states. Reaction of community participants to the dissemination or influence of information within the subgroup over a period of time $[t_k, t_{k+1}]$, $k = 0,1,2,...$, is considered as a process of transferring information content on the principles of heat conduction or diffusion. The final state in each subgroup, by analogy with heat transfer processes, will be called the heating level, which, by the way, partially corresponds to the rhetoric of describing the states of different social groups.

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Thus, in such a formulation, the problem of modeling information dissemination is reduced to the formalization of the dynamics within each community cell, the final state of which will determine the external state of the automata cell for further application of transition functions and formation of output signals in the CA system.

Applying a mechanistic approach to modeling the processes of information dissemination in communities as processes of heat substance transfer, we will consider a method of studying the states of each community taking into account the internal parameters of mutual influence, perception and assimilation of information.

To formalize this process, we will use a model in the form of partial differential equations of the parabolic type (thermal conductivity).

As a model process, the dynamics of which we consider adequate to the schemes of information dissemination in a cell-community, we will choose the physical process of uniform heating of some homogeneous medium (rod, rectangular plate, etc.) to a given temperature. The problem of ensuring the temperature regime at the ends of the rod taking into account the thermal conductivity coefficient (a conditional analogue of the resistance of information perception) is considered in [18]. At the same time, the formal identification of processes in the rod and in the network community requires a more generalized consideration.

It is clear that in real social networks information is distributed on the basis of more complex mechanisms and structures. We will describe the dynamics of the level of awareness within communities using a two-dimensional model of the heat conduction problem on a plane with a point source (center of influence) [19]. Formally, we assume that the process of information dissemination occurs from some conditional central node of the community, each of which is considered as a separate and isolated (without external influence) fragment of the social network. The internal environment for information dissemination in individual cells is formally presented in the form of square regions of a homogeneous plate, within which information is transferred according to the principles of heat conduction.

The mathematically appropriate model of the information dissemination process can be written as

$$\frac{\partial u}{\partial t} = \alpha \nabla^2 u + q_0 \delta(x)\delta(y), (x, y) \in \Omega, t > 0 , \qquad (3)$$

in which the unknown function $u(x, y, t)$ determines the level of awareness in the group (community), α – is the information diffusion coefficient (thermal conductivity), $q_0 = Q_0 /(c\rho)$ – normalized source intensity, δ – Dirac delta-function, $\Omega = [0, L] \times [0, L]$ a region that models a fragment of a social network [19].

Let us define the Neumann boundary conditions taking into account the isolation of the boundaries:

$$\left.\frac{\partial u}{\partial \vec{n}}\right|_{\partial\Omega} = 0 , \qquad (4)$$

where $\vec{n}$ – unit vector of the external normal to the boundary of the domain $\delta\Omega$. For a square domain this means

$$\left.\frac{\partial u}{\partial x}\right|_{x=0} = 0 , \left.\frac{\partial u}{\partial x}\right|_{x=L} = 0 , \left.\frac{\partial u}{\partial y}\right|_{y=0} = 0 , \left.\frac{\partial u}{\partial y}\right|_{y=L} = 0 . \qquad (5)$$

The initial condition has the form

$$u(x, y, 0) = 0, (x, y) \in \Omega . \qquad (6)$$

Let us find the solution of the homogeneous equation using the eigenfunctions of the spectral problem for the Laplace operator with Neumann conditions:

$$\begin{cases} \nabla^2 \phi + \lambda\phi = 0, (x, y) \in \Omega, \\ \left.\frac{\partial \phi}{\partial \vec{n}}\right|_{\partial\Omega} = 0. \end{cases} \qquad (7)$$

Let's apply the separation of variables method $\phi(x, y) = X(x)Y(y)$, as a result we obtain the ratio

$$\frac{X''}{X} + \frac{Y''}{Y} = -\lambda. \qquad (8)$$

Let's put $\lambda = \lambda_x + \lambda_y$. Since the left-hand side (8) is the sum of functions of different variables, we have

$$\frac{X''}{X} = -\lambda_x, \frac{Y''}{Y} = -\lambda_y .$$

Thus, we obtain two independent Sturm-Liouville problems

$$\begin{cases} X'' + \lambda_x X = 0, \\ X'(0) = 0, X'(L) = 0; \end{cases} \quad \begin{cases} Y'' + \lambda_y Y = 0, \\ Y'(0) = 0, Y'(L) = 0; \end{cases}$$

whose solutions, taking into account the Neumann conditions, will have the form

$$X_m(x) = \cos(\pi m x / L), \lambda_{x,m} = \pi^2 m^2 / L^2, m = 0,1,2,...;$$
$$Y_n(y) = \cos(\pi n x / L), \lambda_{y,n} = \pi^2 n^2 / L^2, n = 0,1,2,... .$$

The eigenfunctions of a two-dimensional problem are written in the form

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$$\phi_{mn}(x,y)=\cos(\pi mx/L)\cos(\pi nx/L),$$

$m,n=0,1,2,...$, and the eigenvalues are

$$\lambda_{mn}=\lambda_{x,m}+\lambda_{y,n}=\pi^2(m^2+n^2)/L^2,\ m,n=0,1,2,...\ .$$

Note that the eigenfunctions are orthogonal in the space $L^2(\Omega)$ with norm $\|f\|_{L^2(\Omega)}=\left(\int\limits_{\Omega}|f|^2 d\Omega\right)^{1/2}$:

$$\int\limits_{\Omega}\phi_{mn}(x,y)\phi_{pq}(x,y)d\Omega=\int\limits_0^L\int\limits_0^L\cos(\pi mx/L)\cos(\pi nx/L)\times \times\cos(\pi px/L)\cos(\pi qx/L)dxdy. \quad (9)$$

To find a solution, we construct a Green's function $G(x,y,t;x',y',t')$, that satisfies the equation

$$\frac{\partial G}{\partial t}=\alpha\nabla^2 G+\delta(x-x')\delta(y-y')\delta(t-t'), \quad G=0,\ t<t'. \quad (10)$$

with Neumann boundary conditions.

Let's decompose the Green's function into eigenfunctions

$$G(x,y,t;x',y',t')=\sum_{m=0}^{\infty}\sum_{n=0}^{\infty}a_{mn}(t,t')\phi_{mn}(x,y)\phi_{mn}(x',y'). \quad (11)$$

Substituting this expression into (10), we have

$$\sum_{m=0}^{\infty}\sum_{n=0}^{\infty}\frac{\partial a_{mn}(t,t')}{\partial t}\phi_{mn}(x,y)\phi_{mn}(x',y')= =\alpha\sum_{m=0}^{\infty}\sum_{n=0}^{\infty}a_{mn}(t,t')\nabla^2\phi_{mn}(x,y)\nabla^2\phi_{mn}(x',y').$$

Because $\nabla^2\phi_{mn}=-\lambda_{mn}\phi_{mn}$, we obtain that the Green's function has the form

$$G(x,y,t;x',y',t')=\sum_{m=0}^{\infty}\sum_{n=0}^{\infty}\frac{\varepsilon_m\varepsilon_n}{L^2}\phi_{mn}(x,y)\phi_{mn}(x',y')\times \times\exp(-\alpha\lambda_{mn}(t-t')H(t-t')), \quad (12)$$

where $H(t)=\begin{cases}0, t<0\\ 1, t>0\end{cases}$ – is a Heaviside function, $\varepsilon_k=1,\ k=0,\ \varepsilon_k=2,\ k\ge 1$.

The simulation of the information dissemination process in a social network community takes place taking into account a constant (continuous) source of power, which is due to the following reasons:

– Consideration of such a source corresponds to real processes: information sources operate, as a rule, continuously as instant impulses (news, posts on a social network) during the observation time;

– Under selected conditions, a cumulative effect of informational influence is observed, i.e. repeated messages enhance the overall effect;

– In this case, the process becomes stationary as a result of sufficiently long-term observation, which allows us to assess the maximum level of awareness in the subgroup (community).

Mathematically, this option means that if there is a power source q_0 at the point $(0,0)$ then we have a sequence of instantaneous pulses of magnitude $q_0 dt'$ at time moments $t'\in[0,t]$, each of which creates a response $G(x,y,t;0,0,t')q_0 dt'$.

Applying the superposition principle, we integrate the contributions of all the impulses

$$u(x,y,t)=q_0\int\limits_0^t G(x,y,t;0,0,t')dt'. \quad (13)$$

Substituting (12), we obtain the relation

$$u(x,y,t)=q_0\sum_{m=0}^{\infty}\sum_{n=0}^{\infty}\frac{\varepsilon_m\varepsilon_n}{L^2}\phi_{mn}(x,y)\phi_{mn}(0,0)\times \times\int\limits_0^t\exp(-\alpha\lambda_{mn}(t-t')dt',$$

and after transformation we finally have

$$u(x,y,t)=q_0 t/L^2+q_0/L^2\sum_{m=0}^{\infty}\sum_{\substack{n=0\\(m,n)\ne(0,0)}}^{\infty}\varepsilon_m\varepsilon_n\cos(\pi mx/L)\times \times\cos(\pi ny/L)(1-\exp(-\alpha\lambda_{mn}t))/\alpha\lambda_{mn}. \quad (14)$$

First addend $q_0 t/L^2$ corresponds to the average level of awareness in the group, which increases linearly with time, and the second one describes the spatial distribution of deviations from the mean value.

Omitting the proof of convergence of the obtained series, we obtain that the series (12) allows you to calculate the level of awareness $u(x,y,t)$ at any point $(x,y)\in[0,L]^2$ at any time $t>0$.

Note that the proposed approach can be generalized to the case of formalizing the community as a rectangular region, which is not considered in this article.

4 EXPERIMENTS AND RESULTS

As experimental research, the construction of a solution for determining the levels of awareness in each community of the CA system, which is formalized in the form of a square region with a central source of influence (heating), was considered.

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Each square area of size $L \times L$ is heated from a central point with coordinates $(L/2, L/2)$, and the overall temperature (awareness) distribution is formed by the method of superposition of mirror images. In other words, the desired solution can be represented as the sum of four solutions with the source at the corner point:

$$u_{center}(x,y,t) = u_{corner}(x,y,t) + u_{corner}(L-x,y,t) + \\ + u_{corner}(x,L-y,t) + u_{corner}(L-x,L-y,t). \quad (15)$$

Physically, this means that each square region is divided into 4 quadrants, in which a solution is built based on the proposed approach in the presence of an angular source, resulting in a symmetrical distribution of awareness around the center of influence.

As an example, the problem of determining the levels of awareness in the community based on the heat conduction model with a point source for square plates measuring 1.2m x 1.2m and 1.5m x 1.5m and the parameters $\alpha = 0.01$ m²/s, $T_1 = 100^\circ$, $t_{\max} = 50c$ are considered.

The size L is determined from the condition that in the available time $t_{\max}$ the information will have time to reach a characteristic level of awareness within each community. As a result of experiments, the optimal intensity of information sources q0 is determined under the conditions of applying two optimization modes: time minimization and intensity minimization.

For each square region, the distribution of the level of awareness is calculated as a function of coordinates and time based on the expansion in eigenfunctions of the Laplace operator with Neumann limit conditions.

The results of the calculations and visualization of the distributions are given in Table 1 and Fig. 1, 2 (for L=1.2m).

Table 1 – Results of numerical calculations of propagation modes for different network configurations

Configuration	*Mode*	*Time, t, sec*	*Intensity, $T_{\max}$, °C*	*Power, q_0, W*	*Number of Sources*
1.2m x1.2m $\alpha = 0.01$ m²/s, $T_{\min} = 50^\circ$	max_time max_temp	7.5 10.0	100 75	0.30 0.22	12 12
1.5m x1.5m $\alpha = 0.01$ m²/s, $T_{\min} = 50^\circ$	max_time max_temp	7.5 10.0	100 73	0.50 0.36	12 12

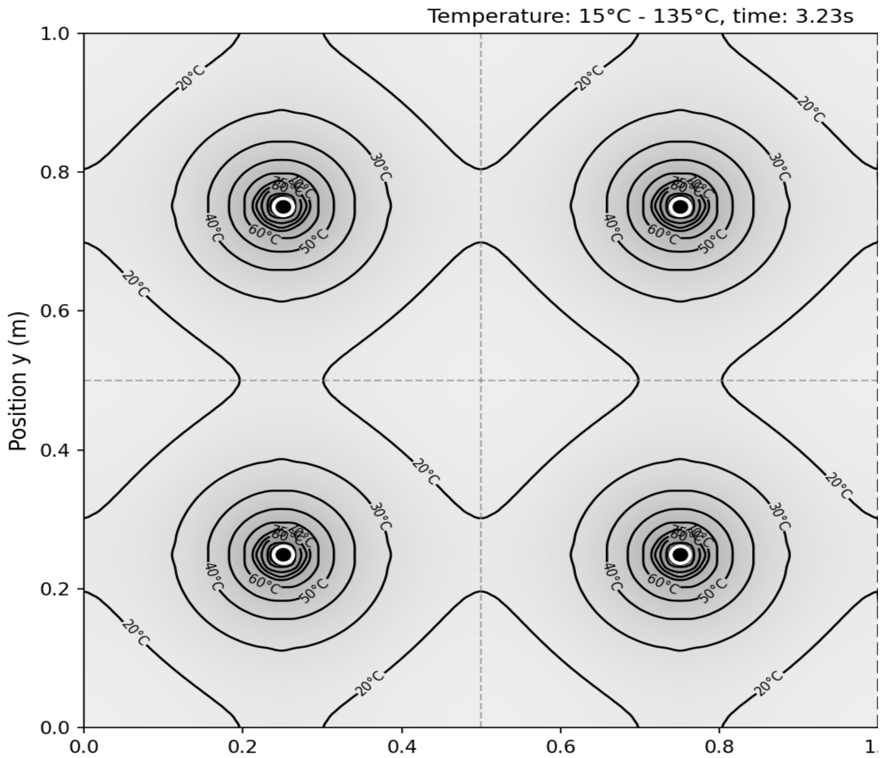

Figure 1 – Temperature distribution at the beginning of the simulation (t = 3.3 s, 33% of the maximum time). The temperature on the plate varies from 15°C to 135°C. The heat is concentrated around the sources

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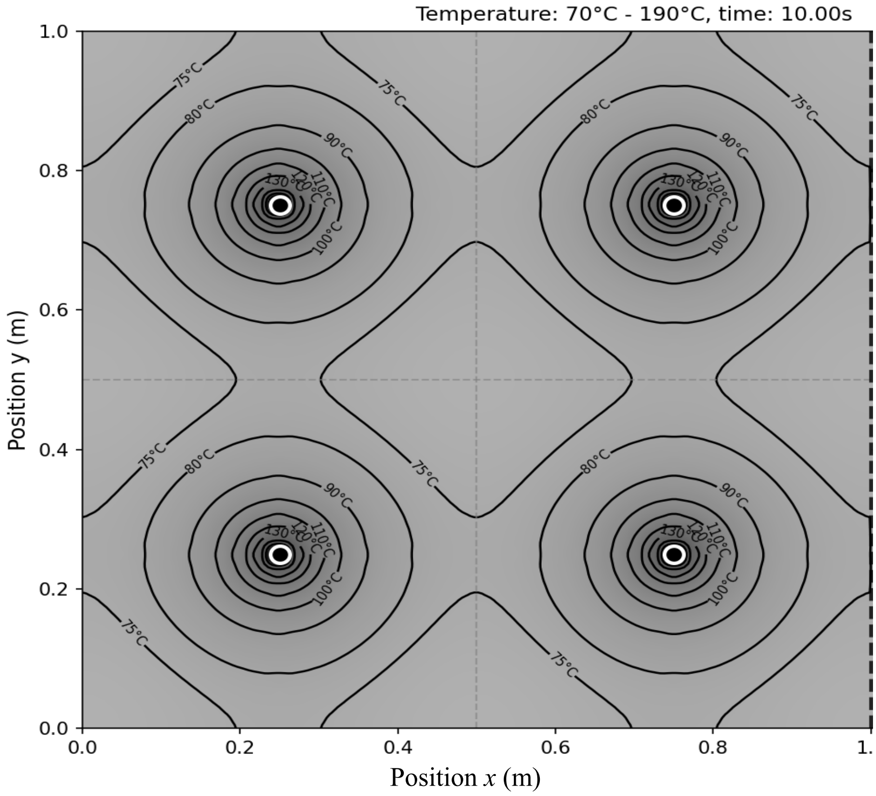

Figure 2 – Final state (t = 10 s). The temperature on the plate varies from 70°C to 190°C. The target minimum temperature of 70°C is reached at all points on the plate

CONCLUSIONS

The proposed work considers the application of the principles of cellular automata models to modeling the dynamics of information dissemination processes. A new approach is proposed, in which, in addition to the automata model, the internal behavior of each cell is considered, provided that its initial state is formed as a result of the influence of some processes inside the cells at each interval $[t_k, t_{k+1}]$, $k = 0,1,2,...$. In other words, a hybrid version of a cellular automata for observing the internal and external dynamics of individual cells is considered, in which the change in the states of the automata model is described by a given transition function with given rules for forming output signals, and a "mechanistic" approach based on the principles of heat conduction is used to formalize internal changes in the state of the cell.

The proposed hybrid model allows us to describe and analyze the processes of information dissemination within a certain social group, which is formed, for example, from subscribers of social networks. In the group, relatively homogeneous subgroups (cells) in the form of communities are distinguished.

Modeling of information processes was carried out taking into account various options of external influence of the environment (on the example of von Neumann and Moore neighborhoods) with explicitly defined transition and output functions. Formalization of internal processes of information dissemination in certain cells is carried out using scalar equations of heat conduction. Numerical calculations of indicators of dynamics of information dissemination in each community and in the group as a whole were obtained, and the solution of information content problems (attitude of participants to a specific problem) in subgroups was proposed based on determining the locations of centers of influence.

In the future, it is planned to consider models of internal dynamics in communities with and without taking into account the influence of environmental conditions, to solve the problem of optimal division of the initial group into separate subgroups by the number of communities. Special attention is required to analyze the method of optimal heating of an asymmetric (rectangular) region that is not divided into a given number of square subregions.

Summing up, it can be stated that the results obtained allowed us to continue researching new ways to study the dynamics of information dissemination in complex social systems based on the use of various models of physical processes.

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DECLARATIONS

Conflict of interest: The authors declare that they have no conflict of interest in relation to this research, whether financial, personal, authorship, or otherwise, that could affect the research and its results presented in this paper.

Authors' contributions: Eugene Ivohin: formulation of the general statement of the problem and research methodology; Larisa Adzhubey: mathematical formalization of the hybrid model for modelling; Yuriy Naumenko: development of an approach to applying the principles of cellular automata to modeling information dissemination processes, Vadym Rets: theoretic results for diffusion model and practical application of developed approach.

Data availability: The manuscript has no associated data.

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Use of artificial intelligence tools: The authors confirm that they did not use artificial intelligence technologies in creating the submitted work.

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ПРО ГІБРИДНИЙ МЕТОД МОДЕЛЮВАННЯ ПРОЦЕСІВ ІНФОРМАЦІЙНОГО РОЗПОВСЮДЖЕННЯ НА ОСНОВІ АВТОМАТНИХ ТА ДИФУЗІЙНИХ МОДЕЛЕЙ

Івохін Є. В. – д-р фіз.-мат. наук, професор, професор кафедри інтелектуальних програмних систем Київського національного університету імені Тараса Шевченка, Київ, Україна. ROR: https://ror.org/02aaqv166. ORCID: https://orcid.org/0000-0002-5826-7408.

Аджубей Л. Т. – канд. фіз.-мат. наук, доцент, доцент кафедри обчислювальної математики Київського національного університету імені Тараса Шевченка, Київ, Україна. ROR: https://ror.org/02aaqv166. ORCID: https://orcid.org/ 0000-0002-8487-0884.

Науменко Ю. О. – канд. техн. наук, доцент кафедри автоматизації та інформаційних технологій Київського національного університету будівництва і архітектури, Київ, Україна. ROR: https://ror.org/02qp15436. ORCID: https://orcid. org/0009-0003-6411-455X.

Рець В. О. – аспірант кафедри системного аналізу та теорії прийняття рішень Київського національного університету імені Тараса Шевченка, Київ, Україна. ROR: https://ror.org/02aaqv166. ORCID: https://orcid. org/0009-0007-8632-7010.

АНОТАЦІЯ

Актуальність. Середовище сучасного інформаційного суспільства в умовах стрімкого зростання засобів обміну інформації та пов'язаної з цим глобалізації даних надає можливість вивчення проблем поширення інформації, дослідження її впливів та створення систем інформаційної безпеки. При розробці систем та технологій розповсюдження інформації широко використовуються методи математичного моделювання. Базовими вважаються теплові, дифузійні або механічні процеси, тобто процеси, що протікають у суцільному середовищі. Серед різних підходів для моделювання часто використовуються рівняння математичної фізики, які є формалізацією фундаментальних законів переносу субстанції.

Ціль. Метою роботи є розробка комплексного формалізованого підходу до числового моделювання динаміки процесів поширення інформації в соціальних мережах на основі використання принципів роботи клітинних автоматів та моделей дифузії. Предметом дослідження є аналіз динаміки рівня інформації, що формується на основі внутрішньої поведінки кожної розглянутої комірки мережі, за умови, що її початковий стан формується в результаті впливу певних процесів поза інформаційними спільнотами.

Метод. У статті запропоновано гібридний варіант моделювання процесів інформаційного розповсюдження на основі клітинних автоматів зі спостереження внутрішньої та зовнішньої динаміки окремих клітин, при чому зміна станів автоматної моделі описується заданою функцією переходів та правилами формування вихідних сигналів, а для формалізації внутрішніх змін у стані клітини застосовується дифузійний підхід на основі принципів теплопровідності. Проведено обчислювальні експерименти з моделювання динаміки поширення інформаційних процесів з урахуванням різних варіантів зовнішнього впливу оточення, наведено розрахунки показників динаміки розповсюдження інформації у спільнотах соціальних мереж.

Результати. Запропонована гібридна модель дозволяє описати та проаналізувати процеси інформаційного поширення в межах деякої суспільної групи, яка формується, наприклад, з підписників соціальних мереж. В групі виділяються відносно однорідні за конкретними показниками підгрупи у вигляді мережевих спільнот.

Проведено моделювання інформаційних процесів з урахуванням різних варіантів зовнішнього впливу оточення (на прикладі околів фон Неймана та Мура) з визначеними у явному вигляді функціями переходів та виходу. Формалізація внутрішніх процесів поширення інформації у визначених клітинах проводиться за допомогою скалярних рівнянь теплопровідності. Отримано чисельні розрахунки показників динаміки інформаційного розповсюдження у кожній спільноті та в групі у цілому, запропоновано розв'язання задач інформаційного наповнення (ставлення учасників до конкретної проблеми) у підгрупах на основі визначення розташувань центрів впливу.

Висновки. У статті розглянуто застосування принципів клітинно-автоматних моделей для моделювання динаміки процесів розповсюдження інформації. Запропоновано новий підхід, в якому додатково до автоматної моделі розглядається внутрішня поведінка кожної клітини за умови, що її вихідний стан формується внаслідок впливу деяких процесів усередині клітин на кожному часовому інтервалі. Іншими словами, розглянуто гібридний варіант клітинного автомату зі спостереження внутрішньої та зовнішньої динаміки окремих клітин, при чому зміна станів автоматної моделі описується заданою функцією переходів з визначеними правилами формування вихідних сигналів, а для формалізації внутрішніх змін у стані клітини застосовується «механістичний» підхід на основі принципів теплопровідності.

КЛЮЧОВІ СЛОВА: моделювання, процеси інформаційного розповсюдження, дифузійні моделі, клітинні автомати, гібридний підхід, соціальні мережі.

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