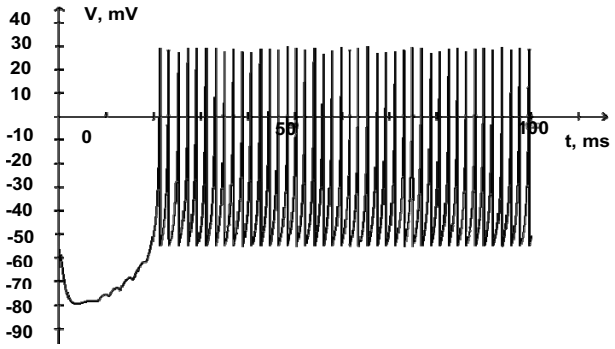

Fig. 10. Neural dynamics for b=0.7

Conclusions. Neurons activity in the cortical column model is changed from bursting to spiking activities when considering from the first to the sixth layer. Researches of synchronization coefficient dependency from changing Izhykevich model' parameters showed:

- presence of parameters, for which the complex neural network dynamics is possible;
- the synchronization coefficient reaches its maximum at:
  - for a=0.03 → k=0.27;
  - for b=0.7 → k=0.365;
- cortical column is less synchronized during changing of parameter a: the synchronization coefficient k – 25−30%;

We can conclude that the time-scale parameter of the membrane potential recovery variable has the weakest influence on synchronization in neocortex. Smaller values result in slower recovery. To enhance synchronization activity in neurons mention above the sensitivity of the recovery variable to the subthreshold fluctuations of the membrane potential should be increased. This fact may be useful for influence on epileptic activity.

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ВПЛИВ ВІДНОВЛЮЮЧИХ ПАРАМЕТРІВ МОДЕЛІ НА МЕРЕЖЕВІ СИНХРОНІЗАЦІЙНІ ХАРАКТЕРИСТИКИ НИЗХІДНОГО ІНФОРМАЦІЙНОГО ПРОЦЕСУ В НЕЙРОННІЙ КОРТИКАЛЬНІЙ СТРУКТУРІ

У роботі досліджено характер взаємодії нейронів у мережах зі складною динамікою, розглянуто явище синхронізації для низхідного інформаційного процесу у кортикальній колонці. Залежність коефіцієнтів синхронізації від варіювання різних параметрів моделі нейрона Іжикевича відображено на відповідних графіках. Для візуальної оцінки синхронізації побудовано растри спайкової активності. Побудовано діаграми для порівняння коефіцієнтів синхронізації на кожному з шарів кортикальної колонки. Показано, що на синхронізацію найменший вплив має зміна часового параметру відновлення мембранного потенціалу.

Ключові слова: коефіцієнт синхронізації, модель Іжикевича, кортикальна нейромережа, низхідний інформаційний потік.

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ВЛИЯНИЕ ВОССТАНОВИТЕЛЬНЫХ ПАРАМЕТРОВ МОДЕЛИ НА СЕТЕВЫЕ СИНХРОНИЗАЦИОННЫЕ ХАРАКТЕРИСТИКИ НИСХОДЯЩЕГО ИНФОРМАЦИОННОГО ПРОЦЕССА В НЕЙРОННОЙ КОРТИКАЛЬНОЙ СТРУКТУРЕ

В работе исследован характер взаимодействия нейронов в сетях со сложной динамикой, рассмотрено явление синхронизации для нисходящего информационного процесса в кортикальной колонке. Зависимость коэффициентов синхронизации от варьирования различных параметров модели нейрона Ижикевича показана на соответствующих графиках. Для визуальной оценки синхронизации построены растры спайковой активности. Построены диаграммы для сравнения коэффициентов синхронизации на каждом из слоев кортикальной колонки. Показано, что на синхронизацию наименьшее влияние имеет переменная временного параметра восстановления мембранного потенциала.

Ключевые слова: коэффициент синхронизации, модель Ижикевича, кортикальная нейросеть, нисходящий информационный поток.

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COMBUSTION REACTOR SIMULATION USING CELLULAR AUTOMATONS

Evolution process in a system of burning fuel in a limited reactor with high-level substance mixing is analyzed. Demonstrated that the system tends toward decreasing total combustion front length and suppressing smaller dissipative structures by bigger ones. It is shown that little temperature noise affects those structures similar to high diffusion. Also the relation between coefficients used in theoretical model and stationary cluster formation is derived.

Key words: burning process, feedback, equilibrium state, dissipative structures, cellular automatons.

Introduction. Ordinary models describing the burning process of a combustion agent use dynamic coordinate-dependent fuel distribution. Such systems are developed for solid or fluid fuels [1, 2] and assume using the inhibitor method to achieve correct results [6].

Another option determining our current interest consists in systems with high-level substance mixing where strong feedback based on general fuel concentration is present.

The examples are high-movable gas jet burning and glow discharge between two flat electrodes. Points of interest in such system are conditions for occurrences of one or another state and their time and parameters variation stability.

In this paper we demonstrate typical solutions obtained by rarely used cellular automatons method [4] and explain why such method was chosen to solve the theoretical

model proposed in [6] for such a system. We show relations between coefficients used in that model and burning cluster formation parameters using simple approximation for stationary solution. According to obtained for 2D system results we can consider natural behavior of flame areas in reactor, which we discuss in the last section.

Theoretical model. Our model for high mixing system includes a certain reactor area with cold walls and instant fuel diffusion in that area. To support permanent general feedback a stream of fuel must come in that system from some direction, equivalent for any area point. Therefore, current model was chosen as 2D model, but it can be optionally extended.

The evolution of the system is ruled by the set of partial differential-algebraic equations, phenomenologically obtained in [6] :

$$\begin{cases} \partial T / \partial t = & n\,q(T) - \gamma\left(T - T_0\right) + \chi\nabla^2 T \\ \partial n / \partial t = & W - n\int\limits_V Q\left(T\left(\vec{r}\right)\right)d\vec{r} \end{cases}, \qquad (1)$$

where main variables are temperature of local point $\mathrm{T} = \mathrm{T}\left(\mathrm{x},\mathrm{y},\mathrm{t}\right)$ and fuel concentration $\mathrm{n} = \mathrm{n}\left(\mathrm{t}\right)$.

The approximate reaction activity functions (heat liberation and fuel consumption) $q(T) = Q(T) = \Theta(T - T_c)$ are interpolated by Heaviside's theta; normalized constant temperature $0 < \mathrm{T} < 1$ refers to reactor walls and $T_c > T_0$ – to the threshold temperature of ignition; the constants γ, χ and W are irradiation, diffusion and fuel income coefficients, respectively.

Terms $\mathrm{n\,q}\left(\mathrm{T}\right)$ and $-\gamma(T - T_0)$ determine the heat income by burning fuel and environmental losses in unit time. The integral term represents general feedback in this system by means of fuel concentration, and $\nabla^2 T$ term is charged with heat conductivity.

Method of solution. To analyze this system we cannot use nor analytic Fredholm methods [7] nor Laplace transform [5]. Moreover, even the numerical method of grids is inefficient in case of unequal number of arguments for all functions. The technique of lines for solving partial differential equations (PDEs) might be better [3], but it is too crocky for dense grids. So, to encapsulate each separate line in that technique it was settled to use cellular automatons [4]. Besides that, such representation allows us to use discreet unit-step instead of exponential fuzzy-step functions, which have to be the substitution for Heaviside's theta to achieve the integration convergence of the system. Such approach simplifies the evaluation process and increases its precision.

Stationary solution. Our goal is to obtain estimate parameters for 1D model and use them in following 2D simulations. The main problem in stationary version of initial system (1) is how to get rid of integral multiplier and Laplace operator.

Let us suppose a system state with mostly constant burning area. This condition is valid for a static or slow dynamic equilibrium. On the basis of used Heaviside's theta functions we can assume the constant temperature and zero laplacian across reactor's cold T_0 and burning T_F zones except a sufficiently narrow band ΔL along burning fronts

$$\text{Cold:} \begin{cases} 0 = & 0 \\ T_0 = & const \end{cases}, \qquad (2)$$

$$\text{Burn:} \begin{cases} 0 = & n - \gamma\left(T_F - T_0\right) \\ n/\gamma = & T_F - T_0 \end{cases}. \qquad (3)$$

In such a case, area ratio $\delta S = S_{burn} / S_{\Sigma}$ provides the value of integral in (1). Using (3) one can write down expression for fuel concentration

$$\text{Fuel:} \begin{cases} 0 = & W - n\,\delta S \\ n = & W / \delta S \\ W/\gamma = & \delta S(T_F - T_0) \end{cases}. \qquad (4)$$

The last two zones with temperature $T_0 < T_1 < T_c$ and $T_F > T_2 > T_c$ correspond to narrow band ΔL between cold (2) and burn (3) areas. It's the only place where diffusion in our model exists

$$\text{Lower:} \begin{cases} 0 = & -\gamma\left(T_1 - T_0\right) + \chi\nabla^2 T_1 \\ \chi/\gamma = & \left(T_1 - T_0\right) / \nabla^2 T_1 \end{cases}, \qquad (5)$$

$$\text{Upper:} \begin{cases} 0 = & n - \gamma\left(T_2 - T_0\right) + \chi\nabla^2 T_2 \\ \chi/\gamma = & \left(T_2 - T_0\right) / \nabla^2 T_2 - n/\gamma \end{cases}, \qquad (6)$$

where T_1, T_2 are some arbitrary points of this front.

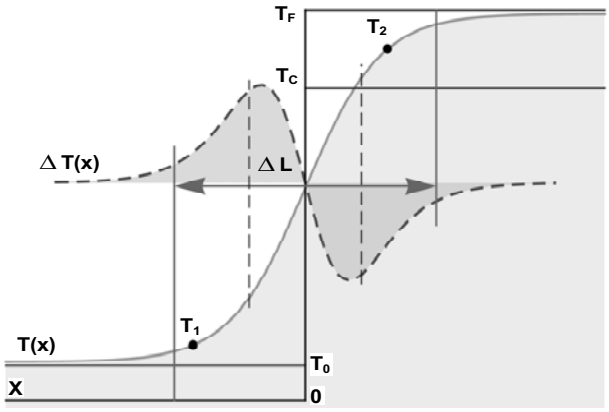

Fig. 1. Fuzzy step function representing the approximate flame front with appropriate sectors, where T(x) and its second derivative reproduce each other and central sector where not

From (5, 6) one can see how front and diffusion curves constantly follow each other to maintain constant value. It allows us to approximate the combustion front by exponential fuzzy threshold function

$$F\theta(x) = \frac{1}{1 + \exp(-sx)}, \qquad (7)$$

$$T(x) = (T_F - T_0)F\theta(x) + T_0, \qquad (8)$$

$$\nabla^2 T(x) = -s^2(T_F - T_0)(\ldots). \qquad (9)$$

On Fig. 1 the plotted curve pieces out of dashed vertical lines are well concerted. Of course, in the central part of the diffusion curve between those lines our fuzzy theta approximation is not appropriate. But we can consider there some monotonous function and phenomenologically adjust results by perforce.

We can obtain constrain on from derived dependence $T / \nabla^2 T = const$ in (5, 6) indifferently. Let us distribute $T(x)$ to Taylor series and choose terms that keeps constant ratio. Such correction is permitted on the score of the above-mentioned contradiction

$$\frac{T(x) - T_0}{\nabla^2 T(x)} = \frac{(\frac{1}{2} + \frac{sx}{4} - \frac{s^3 x^3}{48} + \ldots)}{s^2 f_{\Delta}(x)} = const, \qquad (10)$$

$$\chi/\gamma = \frac{sx f_E(x)}{s^2 f_{\Delta}(x)} \sim 1/s, \qquad (11)$$

where $f_{\Delta}(x)$ include the rest laplacian terms in (9), and $f_E(x)$ is some phenomenological compensating function.

Taking into account the similar normalized dependence for other parameters, next we can equate terms with each

other $\chi/\gamma = 1/s$. Let us try to find the front width $\Delta L = 2d$ as band where laplacian effective influence is $\zeta = 90\%$:

$$\int_0^d \partial_{xx} F\theta(x)dx = \zeta \int_0^\infty \partial_{xx} F\theta(x)dx, \quad (12)$$

$$\tanh^2(d\,s/2) = \zeta, \quad (13)$$

$$(2/d)\,\mathrm{arctanh}(\sqrt{\zeta}) = s, \quad (14)$$

hence $\chi/\gamma = \Delta/7.27$. It is convenient for us to substitute the equilibrium fuel concentration with $n_s = 1$ and replace $T_F - T_0$ with ΔT_F:

$$\begin{cases} W = \delta S \\ \gamma = 1/\Delta T_F \\ \chi = \Delta L^2/(7.27\,\Delta T_F) \end{cases}. \quad (15)$$

Assuming given values, for instance $T_0 = 0.2, \Delta T_F = 1$ $\Delta L = 20, \delta S = 0.4$, we can obtain typical parameters for further simulation.

Cellular automatons system conversion. Cellular automatons (CAs) are n-dimensional elements of space with determined rules of state changing for each discreet iteration of the evolution process [4]. On purpose of tensor representation and storage of CAs, the square space quantization will be used instead of more isotropic hexagonal quantization. The CAs consistent with the reactor walls have to be in constant state and therefore processed separately.

The general fuel concentration could be described by a separate unit CA. But in general case one have to use two interacting CA structures for representation the system with distributed fuel concentration dependent on location.

Classical discreet states of CAs will be replaced by continuums of temperature and concentration. Thus, state changing rules could be described in terms of absolute value increments.

In terms of discreet time and space, the evolution process with units *dt* and *h* has such iterative rules for separate CA at $\{x, y\}$:

$$\begin{cases} T_{t+dt} \to T_t + (\Delta T + \chi \nabla^2 T + \delta T)\,dt \\ n_{t+dt} \to n_t + (W - n_t N_{(T>T_c)}/N_\Sigma)\,dt \end{cases}, \quad (16)$$

where N_Σ corresponds to the total amount of CAs and δT is some temperature fluctuation, which has some applications for simulation experiments. The temperature distribution is scalar field with isotropic diffusion, so using finite differences form of the second derivative

$$T_{xx}(x_0, t) \simeq \frac{T(x_0 + h, t) - 2T(x, t) - T(x_0 - h, t)}{h^2}, \quad (17)$$

we can simplify laplacian in (16) to term of 9-neighbor totalistic CA

$$\nabla^2 T_{x,y} \to (\sum_{i,j}^{-1,0,1} T_{x+i,y+j} - 9T_{x,y})/h^2. \quad (18)$$

Apparently, it seems as crude approximation. But the single difference consists in a little front position deviation from analogous front in a continuous space. Considering $h = 1$ and exposing ΔT let see what we get

$$T_{t+dt} \to T_t + (n_t \Theta(T_t - T_c) - \gamma(T_t - T_0) + \delta T + \chi(\sum_{i,j}^{-1,0,1} T_{x+i,y+j} - 9T_{x,y}))\,dt \quad . \quad (19)$$

$$n_{t+dt} \to n_t + (W - \frac{n_t}{N_\Sigma} \sum_{k=1}^{N_\Sigma} \Theta(T_t^k - T_c))\,dt$$

The smaller time step the more accurate solution we obtain. Case of sufficiently small step is complete analog to numerical method of lines applied to PDEs. The opposite case reveals unstable behavior with possibility of system transformation into a pacemaker (emergent regimes can be interesting per se, but not in this case). So, there is a sense in usage of the variable time step for more precise evaluation in quick phases or more draft in slow phases.

Simulation results and discussion. Effect of the moving front shows itself only in highly diffusive systems in way of Fig. 2.

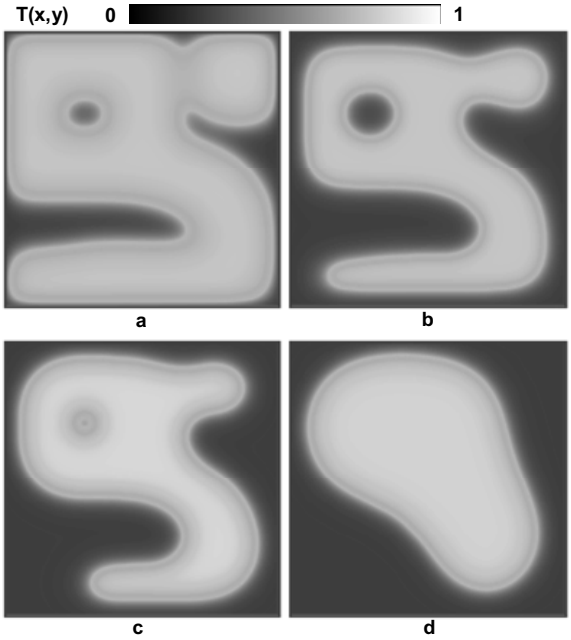

Fig. 2. The evolution process (a-d) trending towards reducing the active front length and smoothing separate details in highly diffusive systems. $\Delta T = 0.4, \Delta L = 20, \delta S = 0.6$

When flame temperature became sufficiently high, the burning front spreads across reactor's area. However, spreading reduces to temperature drop and for $T_F < T_{Fstat}$ the opposite process advances, until irradiation would be balanced by diffusion.

To avoid the influence of described 'front optimization' processes and to see only feedback's effects the diffusion have to be small (see Fig. 3).

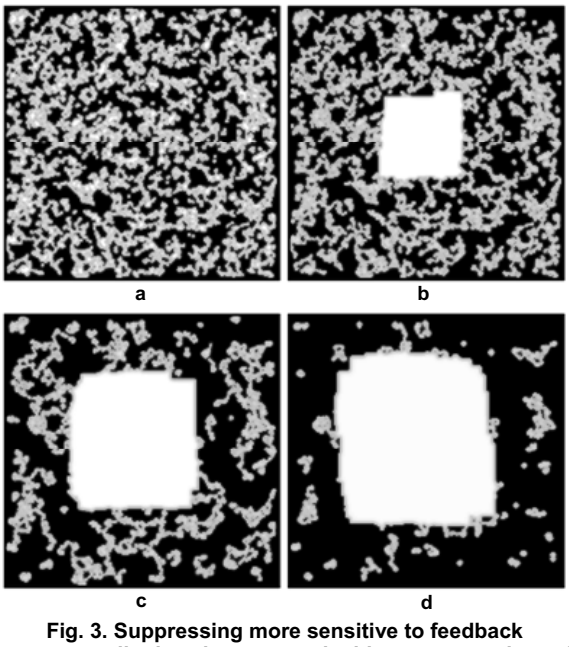

Fig. 3. Suppressing more sensitive to feedback changes smaller burning centers by bigger centers brought on purpose in stationary state (a). $\Delta T = 0.8, \Delta L = 4, \delta S = 0.5$

If we bring into system a big local flame center like Fig.3(b), we can see how smaller centers gradually disappear. Such 'energy transfer' effect is consequence of the instant fuel concentration drop after intentional flame initiation. This 'inertness' make smaller clusters be more liable to any changes in system.

Basic process tendencies reveal itself in the presence of little noise at Fig. 4.

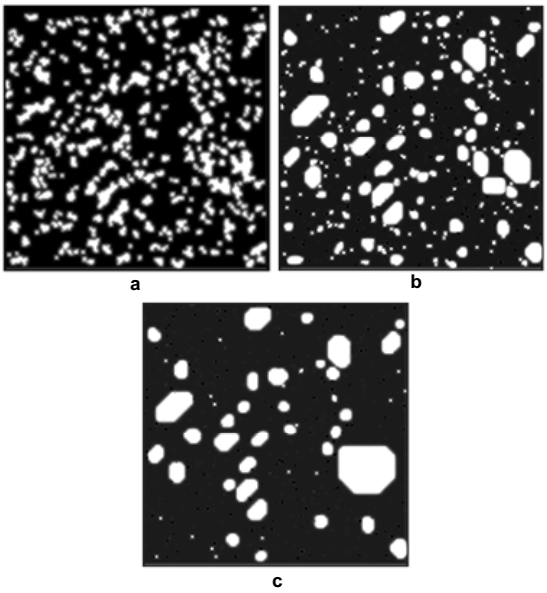

Fig. 4. Little noise affecting the stationary state (a) of low-diffusion systems similarly to Fig. 2 and Fig. 3 altogether. $\Delta T = 0.5, \Delta L = 3, \delta S = 0.4$

Energy redistribution in such a case inclines to reduction of smaller and growth of bigger clusters, which are steadier to fluctuations, like it was shown in Fig. 3. Moreover, in case of insignificant diffusion noise simulates processes similar to Fig. 2 and results in the front shape optimization, which is not implemented otherwise.

Temperature's fluctuations on the brink of combustion when $T_c - T_0 \ll T_0$ and fuel's concentration $n \gg n_s$ lead to massive explosion starting from the active center like in Fig. 5.

Because of the fast confluence, this center arises and draws up piece of general resources through feedback. Therefore, small clusters are fired much later or can't even be fired at all. After explosion, clusters become crumbled up and almost evenly distributed. Long iteration period later, they must unite like in Fig. 4, but in the beginning such behavior is unobservable because of almost equal cluster sizes.

Conclusion. We have analyzed the evolution process of burning in the systems with high-level substance mixing using the cellular automatons method. Discovered behavior is in agreement with the real nature processes and tends to the equilibrium minimal-energy states in spite of kind of system. Such principle takes the form of rounding the burning area boundaries and the dominant stability of the bigger formations. And it makes no difference between high-diffusion and noisy systems in general tendencies.

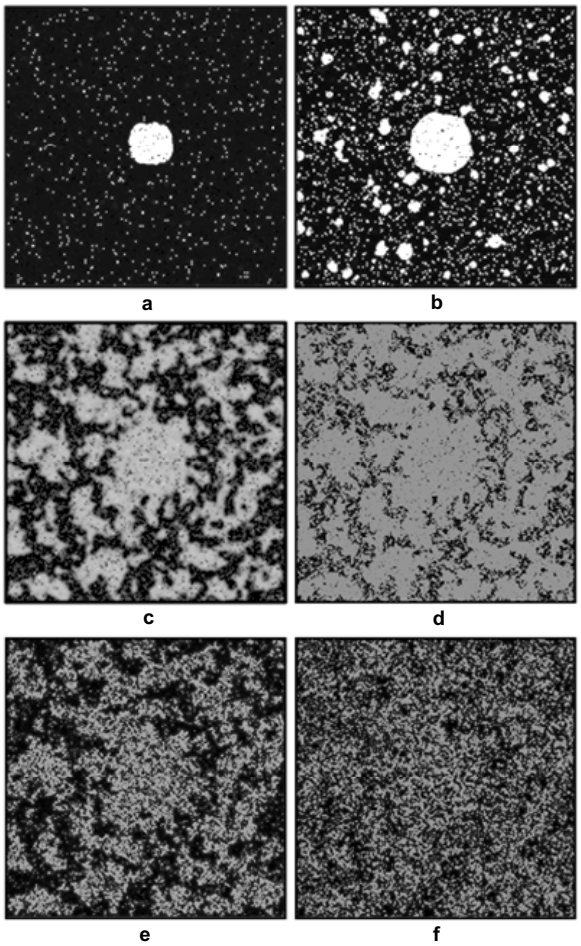

Fig. 5. Consecutive stages of the explosion under little noise influence starting from high fuel concentration (a) till stationary (f). $\Delta T = 0.05, \Delta L = 3, \delta S = 0.5, n = 10 n_s$

The applied cellular automatons approach is very scalable and flexible, so CAs could be used for analyzing very wide range of systems. It could be loose and imprecise in questions of front microstates but makes it possible to observe general tendencies on the fly.

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МОДЕЛЮВАННЯ ГОРІННЯ В РЕАКТОРІ ЗА ДОПОМОГОЮ КЛІТИННИХ АВТОМАТІВ

Проаналізовано еволюцію згоряння палива в обмеженому реакторі для системи з сильним перемішуванням речовини. Продемонстровано тенденцію системи зменшувати загальну довжину фронту горіння та подавляти менші дисипативні структури більшими. Показано, що малі теплові шуми в системі діють на ці структури подібно до підвищеної дифузії. Також виведено зв'язок між коефіцієнтами, використаними у теоретичній моделі, та стаціонарними кластерними утвореннями.

Ключові слова: процес горіння, зворотній зв'язок, рівноважний стан, дисипативні структури, клітинні автомати.

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МОДЕЛИРОВАНИЕ ГОРЕНИЯ В РЕАКТОРЕ С ПОМОЩЬЮ КЛЕТОЧНЫХ АВТОМАТОВ

Проанализировано эволюцию сгорания топлива в ограниченном реакторе для системы с сильным перемешиванием вещества. Продемонстрировано тенденцию системы уменьшать общую длину фронта горения и подавлять меньшие диссипативные структуры большими. Показано, что малые тепловые шумы в системе воздействуют на эти структуры подобно повышенной диффузии. Так же выведена связь между коэффициентами, использованными в теоретической модели и стационарными кластерными образованиями.

Ключевые слова: процесс горения, обратная связь, равновесное состояние, диссипативные структуры,

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CLUSTERING OF CONCEPTS BY MEANS OF THE INTERNET

The approach to text information analysis using data from the Internet by example of clustering of concepts is considered in this paper. The problem of clustering of concepts is reduced to the problem of partition a graph into subgraphs in the case of not known in advance quantity of subgraphs. The algorithm of graph partitioning by the target function optimization is proposed, as well as the form of the target function for concepts clustering. The results are verified by experimental data.

Keywords: clustering, text analysis, graph partitioning, optimization.

Introduction. Possibility of automated text analysis is demanded by variety of problems. But a text is, as a rule, weakly formalized and its content can be defined only through the context, because the meaning of a specific word may differ depending on its interrelation with surrounding words. This fact causes impossibility of usage for creation such a text analysis system of the approach that is typical for compilers and interpreters of programming languages and requires existence of database which would integrate the concepts, words designating these concepts, and their interrelations. Such a database can be developed by transfer knowledge from a person or persons to some system that would save this knowledge in a suitable form. Difficulty and laboriousness of direct performing such a task is obvious.

Nevertheless human race has accumulated tremendous volume of mentioned above knowledge in the form of text. This form of data saving is comfortable and habitual for people but it cannot be used as automated knowledge base. That is why is seems natural to try to analyze existing texts and to build a database on their basis – this idea enables to take advantage of the work already made instead of doing it from the very beginning.

So the goal of the research is verification of proposed approach for building database on the example of semantic clustering of the concepts.

Generally, a text written by a person and appointed for understanding by other people contains concepts related in meaning. Respectively, a measure of cohesion for the pair of concepts can be obtained by means of analysis of frequency of appearance of the word pair in a text. In its simplest case, this approach cannot enable the construction of the knowledge base in a form offered in semantic web [1], when pair of concepts is connected by the third concept, but it gives the possibility to group the words to the clusters by themes.

At the moment the Internet contains huge amount of information. This fact, as well as simple access to this information, allows its using as the source of existing texts. A web page identified by URI is assumed as a text unit. With these assumptions, the task of separation the words into semantic clusters is reduced to the analysis of frequencies of appearance of the word pairs at the same URI and then to the association of the words into groups according to their meanings.

Thus, the problem is formulated in terms of concepts (represented by appropriate words) and measure of cohesion between these concepts. It makes possible to consider the set of input data as a weighted graph and reformulate the problem to the problem of optimal partition of the graph into subgraphs by criterion of "semantic cohesion". This problem is of NP-complete problems type, so precise methods, e.g. brute-force search, have no use because of their computational complexity.

Practically applicable algorithms of partitioning the graph, as a rule, allow finding not a global optimum for the task but some optimal result satisfactory for practice or, in more difficult cases, some optimum that can be obtained in limited time. In this way, precision and accuracy of algorithm is superseded by speed at the expense of the fact that direction of further search of optimum is defined in every local point. In result, the algorithm cannot assure finding of a global optimum and more, the result depends on a choice of the initial point.

Development and discussion.

Quality criteria of graph partitioning. Semantic cohesion and respectively optimal partitioning for semantic cohesion are not the determined concepts and cannot be strictly defined because of subjectivity of concept of meaning of a word per se. But solving the problem demands to determine some, though subjective, quality measure of optimal graph partition.

Some requirements for graph partitioning may affect properties of this subjective quality measure. These requirements can be formulated as follows:

- Graph vertices inside a cluster must be bound more strongly than vertices from different clusters.
- Clusters have not obligatory equal sizes, the more so the themes corresponding to clusters can contain different quantities of concepts.
- Quantity of clusters is not known in advance.

Nevertheless, there is need in some reasonable expectations about quantity of clusters. The matter is that all the concepts are connected somehow or other and, therefore, all of them have to be united in the only cluster. On the other hand, every concept differs from others and, therefore, has to be contained in individual cluster. These are extreme two cases of the choice of threshold value of cohesion at which concepts are united in a cluster. Obviously, the value of threshold cohesion affects quantity of clusters, i.e., scale at which all the system is considered. It is clear as well that a single objective function, suitable for all possible cases, cannot exist and that the objective function has to depend on the parameter which determine where is the boundary between different themes (and corresponding clusters). Evidently, this parameter has to be chosen on the basis on the characteristics of specific problem.

Some arbitrary threshold value of cohesion measure can be used in certain situations. But such an approach has an obvious disadvantage: the value is not absolute