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На основі проведених експериментальних досліджень встановлено, що при словесній розбірливості менш 20–30 % важко встановити навіть предмет ведення розмови, а при розбірливості мови менше 10 % – це неможливо. Надійне маскування досягається в тому випадку, коли отримана зашумлена мова має словесну розбірливість не більше 20 % (на практиці це відповідає сприйняттю окремих вигуків і окремих «знайомих» слів).

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ВЛИЯНИЕ ОСОБЕННОСТЕЙ КАНАЛОВ УТЕЧКИ ИНФОРМАЦИИ НА РАЗБОРЧИВОСТЬ ПЕРЕХВАЧЕННЫХ РЕЧЕВЫХ СООБЩЕНИЙ

Исследована защищенность акустических каналов утечки информации. Построена зависимость словесной разборчивости речи от отношения сигнал/помеха и сигнал/белый шум. В качестве помех выступали характерные для офисного помещения акустические сигналы. Выявлено влияние на разборчивость речи семантической составляющей в сообщении и возможность её многократного прослушивания. Установлено, что для гарантированной защиты речевой информации должно быть реализовано отношение сигнал/белый шум не более 20 дБ.

Ключевые слова: разборчивость речи, семантический текст, утечка информации.

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DEVELOPING THE MODEL OF ECOSYSTEM IN NATURAL DISASTERS CONDITIONS

Розроблено динамічну просторову модель екосистеми в умовах надзвичайних ситуацій природного характеру, призначену для вирішення задач підтримки прийняття рішень. Описано формальну модель динаміки надзвичайних ситуацій природного характеру у вигляді нечітко динамічного топологічного простору. На основі розроблених моделей створено географічну веб-орієнтовану систему підтримки прийняття рішень.

Ключові слова: *територіальна система, відношення нерозрізненості, топологічний простір, клас еквівалентності, надзвичайна ситуація природного характеру.*

1. Introduction

At present the problem of studying and forecasting the natural disaster situations has taken center stage. It's connected with increasing their intensity and frequency as a result of population and industrial-production growth, urban extension, environmental degradation, global warming, etc. Involving new territories in property development, increasing the number of production objects, which can be potential sources of natural disasters, lead to occurrence of natural disasters, giving rise to property damage and sometimes human losses. In recent decades there is a growth not only in a number, scale and intensity of natural disasters but also in a value of damage caused by the disasters. It requires a huge amount of financial resources for elimination of disaster consequences and has a negative impact on socio-economic development of society.

Having regard to the above, the problem of protecting the population and territories against natural disasters is a problem of present interest. The delivery of a set of prevention measures, providing protection of population and territories, is based on reliable estimate of their influence on ecosystems. Implementation of such measures allows to develop a set of protective actions and to determine a value of reserve to provide socially acceptable level of natural risk.

2. The object of research and its technological audit

Natural disaster is considered as a component of ecosystem – integral territorial entity, which is formed in close interaction between natural and artificial objects. Ecosystems make for a class of systems with the following features:

1) they have spatial reference;

2) they combine the models of territory, natural and artificial objects;

3) they have multilayer structure: the first layer makes for territorial system (the model of terrain), the second layer makes for natural disaster model.

Natural disasters make for a class of destroying processes, damaged territorial systems and having the following characteristics:

1) they propagate in space and time;

2) they arise suddenly, so that they are difficult in prevention;

3) they run in uncertainty conditions;

4) they cause damage to the elements of ecosystem;

5) they run in time and resources shortage conditions.

The tasks of decision making which require forecasting the influence of natural disasters on ecosystems, are crucial for such kind of processes. At the present time there are no scientifically based methods of decision making for above mentioned classes of systems and processes.

3. The aim and objectives of research

The aim of research is to build an approximate spatial model of ecosystem in natural disaster conditions, which has to be suitable for the tasks of decision making against natural disasters, using the methods of topology theory, as well as fuzzy set theory.

The following tasks have been solved:

1. To build a static model of ecosystem in the form of topology space induced by indiscernibility relation.

2. To develop a dynamic model of ecosystem in natural disaster conditions in the form of dynamic topology space.

4. Research of existing solutions of the problem

At the present time much has been done in the field of natural disasters modeling.

In [1–4] this task is solved using methods of statistical analysis for retrospective databases. But insufficient observability of events related to natural disasters occurrence and poor accuracy of environment parameters prevent obtaining reliable predictions, which deteriorates the value of independent applying the statistical methods.

In [5–8] the detailed mathematical models of physical-chemical processes taking place during natural disaster in a certain environment state in homogeneous segments of terrain are used. They allow giving a reasonable approximation for a boundary of natural disaster contour at any given point in time. The drawback of these models is their high computational complexity.

In [9] the natural disaster model is much simplified, resulting in speeding up the calculations and decreasing their accuracy, so that the credibility of situation assessment is also decreased.

According to the literature analysis it may be concluded that the system response speed, needed for decision maker, can be achieved by developing the adequate spatial model of the territory in natural disaster conditions. Incompleteness and inaccuracy of defining the different events characteristics, common to natural disasters, allow softening demands to the accuracy of input information representation. In consequence, the required system response speed can be achieved using some roughening (blurring) of the spatial model, which allow decreasing the requirements as to natural disaster model in terms of accuracy [10, 11].

So, despite the active research, using the traditional approaches for the class of processes under consideration, don’t provide the required speed of response and acceptable efficiency of decision support system. It stipulates the timeliness of this research.

The topological spaces will be used for spatial modeling of the ecosystem in natural disaster conditions. The methods of fuzzy sets theory will be used for blurring the spatial model of natural disaster [12].

5. Methods of research

The natural disaster spreads within a certain terrain (territory), the model of which is represented as territorial system (TS) Ξ. TS model is represented in the form of subspace X of two-dimensional Euclidean space with given norm, metric and overlapped lattice of square cells of equal area [10, 11].

Each point of the subspace X has a set of attributes:

$$A = A_S \cup A_D,$$

where A_S – a set of static attributes (describing the terrain characteristics); A_D – a set of dynamic attributes (changing when the point is reached by natural disaster).

A set of environment parameters such as wind speed and direction, air humidity, air temperature are separated in a set A_E (Fig. 1). The key feature of these attributes is the fact that their values don’t connected to a certain point in space.

The static model of TS unaffected by natural disaster is built to solve the first task of the research (building the static model of ecosystem).

A base structured element of ecosystem, as well as a key link in a task of spatial reference, representation and analysis of the information about territories exposure

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to natural disasters is a *geotaxon* $g \subset X$. Geotaxon is an object with the following properties:

1) reference to the coordinates of the space X;

2) clarity (a decision maker deals with the above-noted objects in his daily work);

3) uniformity (in terms of the certain attribute's values);

4) comparability (the descriptions of the objects should allow comparing objects adequately).

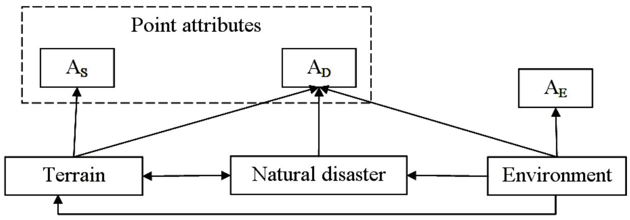

Fig. 1. Point attributes

Decomposition of the space X into geotaxons follows Pawlac's indiscernibility relation based on the set of static attributes A_S and forms static topological space $T_{G_X}^{A_S}$ [13, 14]:

$$T_{G_X}^{A_S} = \left(X,\ Def\left(G_X^{A_S}\right)\right), \quad (1)$$

where $G_X^{A_S}$ – a set of geotaxons; $Def\left(G_X^{A_S}\right)$ – a family of compound sets composed of the set of geotaxons.

Topological space (1) is induced by A_S-indiscernibility relation dividing the space X into disjoined equivalence classes, each of which can be disconnected in general case (Fig. 2). Geotaxons can be pairwise disjoint sets, which are connected components of topological space, and their disjunctive union coincides with the set X.

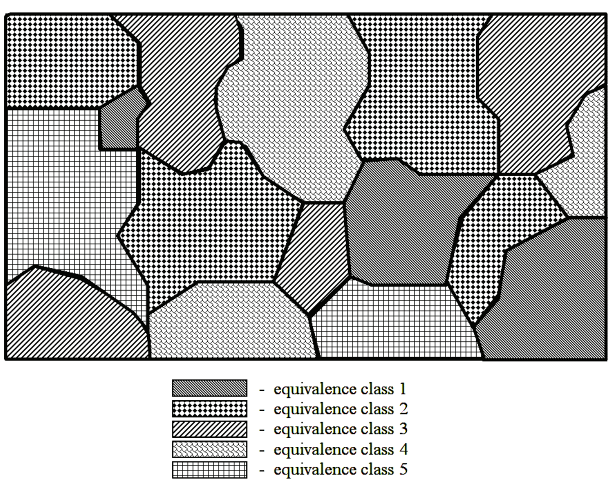

Fig. 2. Topological space induced by equivalence classes

So, geotaxon is connected and homogeneous in terms of the values of static attributes A_S subspace. In general case the homogeneity property can be considered in terms of different subsets of state parameters (variants). Moreover, the equality operator can be assigned strictly (as equivalence relation) or non-strictly (as likelihood relation). In the last case non-strict equality of the values of state parameters gives the opportunity to «blur» the boundaries of geotaxons.

It should be noted that statistics in the most of modern geoinformation systems (GIS) is being gathered with reference to the numbered homogeneous sectors of the terrain. The properties of these sectors fit with geotaxon definition. It allows considering the geotaxons in GIS as the homogeneous sectors of the terrain and using them for modeling the ecosystem static.

To model the dynamics of the ecosystem in natural disaster conditions (the second task of the research) the TS is discretized by smaller cartographic objects using a grid of square cells of equal area C, which allow switching from continuous form of geoinformation within the geotaxon to a discreet one on a scale of separate cells, each of which is considered to be homogeneous in terms of all attributes from the set A. The cells are used for the modeling of natural disaster dynamics.

Decomposition of the subspace X of Euclidean space using the cells is a topological space:

$$T_C = \left(X,\ Def\left(C\right)\right), \quad (2)$$

imposed on the topological space of geotaxons $T_{G_X}^{A_S}$, where $Def\left(C\right)$ – a family of all compound sets, derived from the set of cells C, including an empty set $\varnothing$ and the set C. As distinct from the topological space of geotaxons, which is formed based on the A_S-indiscernibility relation, the topological space of cells is formed using a simple discretization of the space X into the cells of equal area. Cells are mutually disjoint A-indiscernable sets, and their disjunctive union coincides with the set X.

Modeling the natural disaster dynamics over a lattice of cells stands for modeling the change of cell states. Assume a cell goes through a set of qualitatively different categories of states (for example: not enveloped in disaster, enveloped in disaster etc.) – «possible worlds» W_D.

Since each cell belongs to a definite geotaxon, which in turn belongs to a definite equivalence class, induced by A_S-indiscernibility relation, we assume these classes as static possible worlds. A set of such possible worlds is denoted by W_S. Based on the above, a generalized possible world for each cell composed of static and dynamic worlds can be determined. Let us denote a set of generalized worlds as W:

$$W = W_S \times W_D. \quad (3)$$

The whole set of cells C can be subdivided into a subset of cells C^K prone to natural disaster of a definite class K and a set of cells $C^{\overline{K}}$ that are not prone to natural disaster of class K:

$$C = C^K \cup C^{\overline{K}}. \quad (4)$$

The first subset of cells, as distinct from the second one, contains the parameters with the dynamic values from the subset of parameters A_D (Fig. 3).

A binary relation of w_D-indiscernibility, which allows to refer each cell to one of the possible dynamic worlds from the set W_D at any time point, is built on the set of cells C. This relation is an equivalence relation and induces a strict topology, in other words partitioning the set C into the crisp sets of cells:

$$C^{w_i}\left(t\right),\quad i = 1,\ldots,\ n-1,$$

where $C^{w_i}\left(t\right)$ – subset of the cells, which are in the world w_i, n – a number of possible dynamic worlds.

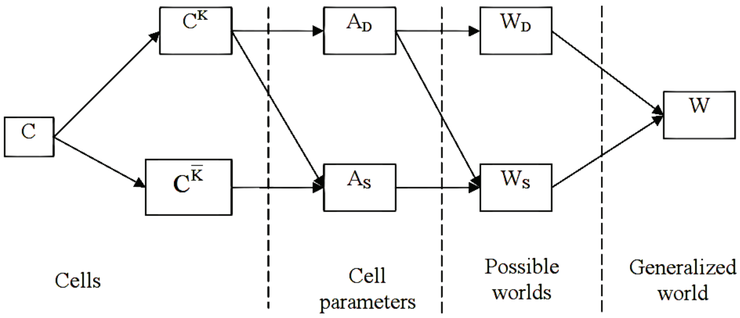

Fig. 3. Cells and possible worlds

The influence of the cell size δ on the time, needed for modeling the spreading of fire with 40000 square meters in area, on the accuracy of fire contour approximation has been investigated in the experiment. The experiments have been conducted under the different cell size but under the same environmental parameters. The cell located within the geotaxon related to the region 15, sector 3 of the forestry have been taken for the fire source. The results of the experiment are shown in the Table 1.

Equivalence classes $C^{w_i}(t)$, $i = 0,\dots, n-1$, induced by the relation $\mathfrak{R}_C^{w_D}$, constitute the model of dynamic of the ecosystem in natural disaster conditions in the form of dynamic topological space $T_C^{w_D}(t)$. Superposition of topological spaces modeling natural disaster dynamics and the set of geotaxons forms a dynamic topological space $T_C^{A_S \cup w_D}(t)$ with connected components being the subsets of $A_S \cup w_D$-indiscernable cells (Fig. 3).

To make this model more realistic, it has been suggested to substitute the strict equivalence relation $\mathfrak{R}_C^{w_D}(t)$ by its fuzzy generalization $\tilde{\mathfrak{R}}_C^{w_D}(t)$, which at any time point t induces a fuzzy approximation space $a\tilde{p}r_C(t) = \left(C, \tilde{\mathfrak{R}}_C^{w_D}(t)\right)$ and fuzzy topology, i. e. partitioning the set of cells C into fuzzy sets of cells $\tilde{C}^{w_i}(t)$, $i = 0,\dots, n-1$, belonging to each of possible dynamic world from the set W_D.

The dynamic topological space induced by the fuzzy relation $\tilde{\mathfrak{R}}_C^{w_D}(t)$ is a model of ecosystem in natural disaster conditions.

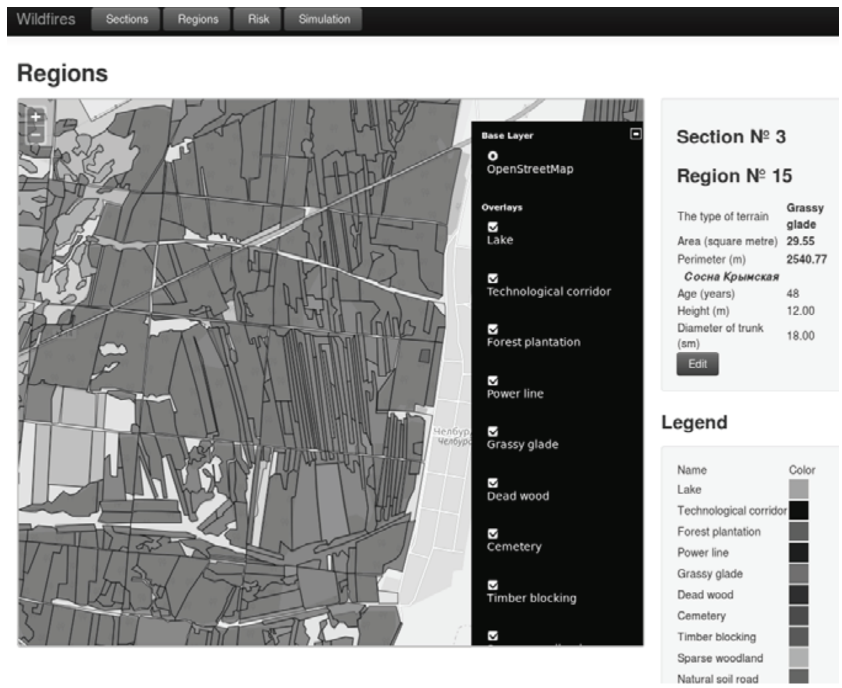

Fig. 4. Representation of the set of geotaxons of Tsurupinsk forestry in Disaster Risk Management project

6. Research results

The model of ecosystem in natural disaster conditions represented in this work is implemented in Python programming language using Django framework and its extension GeoDjango in the form of web-oriented geographical decision support system Disaster Risk Management. OrenLayers library and PostgreSQL data base management system were also used for the development of the project.

The experiments for the assessment of the decision support system response time based on the transition function proposed by Zharikova in [15] have been conducted using created software. The influence of the cell size on the time required for the calculation of the area occupied by fire has been investigated in the experiment. Tsurupinsk forestry of Kherson area (Ukraine) has been chosen for performing the calculations.

Fig. 4 shows the fragment of Tsurupinsk forestry map implemented in decision support system Disaster Risk Management in the form of the set of geotaxons and discretized by a lattice with the changing cell size (δ). Each geotaxon is represented as a homogeneous area with the information from the data base related to this area.

Table 1

Experiment results

No.	Cell size δ, m	Time of calculations, min	Approximation error, %
1	22	5	45,5
2	20	5,5	34
3	18	6	25
4	16	7,5	20,5
5	14	9	15
6	12	9	13,5
7	10	15,5	11
8	8	19	9,5
9	6	32	8
10	4	54	7,5

According to the experiment results represented in the Table 1, the discretization of the space by the lattice of cells with less that 8 meters in size leads to the sharp increase of calculation time, and when the size of the cell is from 18 to 22 meters the approximation accuracy is insufficient.

These performance indicators can be used to choose the optimal exposure of fire brigade and approach roads for fire fighting. It will contribute to decreasing the losses of national forestry in the event of fire.

7. SWOT-analysis of research results

Strengths. The discretization of the considered space by the lattice of cells with less than 8 meters in size leads to a sharp increasing the calculation time. The proposed natural disaster model provides acceptable characteristics in terms of accuracy and response time providing discretization of the space by the cells with the size from 8 to 18 meters.

Weaknesses. The approximation accuracy is insufficient provided that the cell size is from 18 to 22 meters.

Opportunities. Using the proposed ecosystem model to develop risk-oriented models and methods of intellectual decision making in natural disaster conditions is being planned in prospect.

Conducted research can be used for optimal fire response, which leads to minimizing losses of forestry.

Threats. A lack of normative base in Ukraine, regularized the modern methods of natural disaster danger and risk assessment, can influence this research negatively.

8. Conclusions

1. The static ecosystem model in the form of topological space, induced by the indiscernibility relation is built in the research. This allows representing the terrain in the form of the set of homogeneous areas – geotaxons.

2. The dynamic ecosystem model in natural disaster conditions is developed in the form of fuzzy topological space, which allows decreasing the computational complexity and provides adaptability to the conditions of incomplete and inaccurate information.

The dynamic ecosystem model in natural disaster conditions is based on decomposition of the space into a finite set of disjoint homogeneous areas – geotaxons and their further discretization by a lattice of the cells of equal area. The natural disaster spreading dynamics is represented as changing the cell states.

The proposed model can be used in decision support systems for natural disaster resilience, based on GIS. It provides acceptable decision support system characteristics providing the discretization by the lattice of cells with the size from 8 to 18 meters.

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РАЗРАБОТКА МОДЕЛИ ЭКОСИСТЕМЫ В УСЛОВИЯХ ЧРЕЗВЫЧАЙНЫХ СИТУАЦИЙ ПРИРОДНОГО ХАРАКТЕРА

Разработана динамическая пространственная модель экосистемы в условиях чрезвычайных ситуаций природного характера, предназначенная для решения задач поддержки принятия решений. Описана формальная модель динамики чрезвычайных ситуаций природного характера в виде нечеткого динамического топологического пространства. На основе разработанных моделей создана географическая веб-ориентированная система поддержки принятия решений.

Ключевые слова: территориальная система, отношение неразличимости, топологическое пространство, класс эквивалентности, чрезвычайная ситуация природного характера.

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