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FORECASTING METHODS FOR STUDYING AND DETECTING NATURAL PHENOMENA

This article describes ways to research and detect natural phenomena based on forecasting methods and techniques. The purpose of this work is creation of improved algorithm that will allow predicting the occurrence of any kind of natural phenomena based on existing statistics. To create proposed algorithm and software, we used existing forecasting methods and techniques, mathematical and causal methods as well as monitoring current affairs will be considered. Proposed algorithm improvements give us possibility to get general prediction or get prediction for some specific kinds of disaster. Also in that article we propose to combine mathematical methods together with artificial intelligence. AI allow us improve accuracy of prediction and provide possibility to increase number of parameters or characteristics to analysis. As AI is modern and fast-growing technology it provides unlimited ways to improve our algorithm and software not only for forecasting of natural phenomena but also for simulate them, analyze consequences, ways to minimize damage and most important – casualties. One of the main advantages of using proposed combining artificial intelligence with old mathematical and statistics methods over using only mathematical or statistical methods is a flexibility of artificial intelligence in their result as mathematical result stabilize with growing statistics data and each new occurrence will not take so big impact on result. But for artificial intelligence each new data can have a critical effect and can correct all forecasts together with expected consequences. As result of that article new software complex will be implemented and integrated to scientific complex for further improvements, learnings, researches and analysis.
***Key words:** natural phenomena, disaster prediction, perception architecture, neural network, prediction method, disaster monitoring.*

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МЕТОДИ ПРОГНОЗУВАННЯ ДЛЯ ВИВЧЕННЯ ТА ПОПЕРЕДЖЕННЯ НАДЗВИЧАЙНИХ ПРИРОДНИХ ЯВИЩ

У статті описано способи дослідження та виявлення природних явищ на основі методів і технік прогнозування. Метою даної роботи є створення вдосконаленого алгоритму, який дозволить прогнозувати виникнення будь-яких природних явищ на основі наявної статистики. Для створення запропонованого алгоритму та програмного забезпечення ми використали наявні методи та техніки прогнозування, математичні та причинно-наслідкові методи, а також моніторинг поточних подій. Запропоновані вдосконалення алгоритму дають нам можливість отримати загальний прогноз або отримати прогноз для деяких конкретних видів надзвичайних природних явищ. Також у цій статті ми пропонуємо поєднати математичні методи разом із штучним інтелектом. ШІ дозволяє підвищити точність прогнозу та надає можливість збільшити кількість параметрів або характеристик для аналізу. Оскільки штучний інтелект є сучасною технологією, яка швидко розвивається, вона надає необмежені способи вдосконалення нашого алгоритму та програмного забезпечення не лише для прогнозування природних явищ, але й для їх моделювання, аналізу наслідків, способів мінімізації збитків і найголовніше – жертв. Однією з головних переваг використання запропонованого поєднання штучного інтелекту зі старими математичними та статистичними методами перед використанням лише математичних або статистичних методів є гнучкість штучного інтелекту в їхніх результатах, оскільки математичні результати стабілізуються зі зростанням статистичних даних, і кожна нова подія не буде мати такого великого впливу на результат. Але для штучного інтелекту кожна нова інформація може мати критичний ефект і може скорегувати всі прогнози разом з очікуваними наслідками. Як результат цієї статті новий програмний продукт буде впроваджено та інтегровано в науковий комплекс для подальшого вдосконалення, навчання, досліджень та аналізу.

***Ключові слова:** природне явище, попередження надзвичайних явищ, архітектура персептронів, нейронна мережа, метод прогнозування, моніторинг надзвичайних явищ.*

Introduction. Natural disasters are dangerous natural phenomena of geophysical, geological, atmospheric origin which are characterized by sudden destruction, which often leads to numerous casualties among people, destruction of residential infrastructure and also causes numerous secondary disasters. Hazardous natural phenomena occur at different times and on different scales and each of them is unique in its own way. Tornadoes and flash floods are short-term destructive events affecting a relatively small area. Other hazards, such as droughts, develop slowly but can affect almost an entire continent and entire countries within months or even years. An extreme weather event can cause several hazards to occur simultaneously or sequentially. In addition to strong winds and rain, a tropical storm can cause flooding and mudflows. In temperate latitudes, severe thunderstorms can be accompanied by large destructive hailstones, tornadoes, strong winds and rain, leading to flash floods. Winter thunderstorms with strong winds and heavy snowfall or freezing rain can also contribute to avalanches on some mountain slopes and heavy runoff or flooding in the next melt season.There are also human-made threats such as dam failure, chemical spills, radioactive threats, etc. But some of them cannot be predicted when they will appear or where they will fall after they appear.

Some National Meteorological and Hydrological Services and Specialized Centers are responsible for studying geophysical hazards, including volcanic eruptions (airborne ash) and tsunamis, as well as airborne pollutants (radioactive nuclides, biological and chemical agents) and heavily polluted cities [7]. Thanks to them, we are finding new ways to combat natural and human-made disasters.

Disaster monitoring and forecasting. The general goal of monitoring hazardous phenomena and processes in nature is to increase the accuracy and reliability of the forecast of natural phenomena based on a combination of intellectual, informational and technological capabilities of various departments and organizations that monitor certain types of hazards. The monitoring data serve as the basis for forecasting. Also, the more accurate and faster the forecasting data is obtained, the faster and better people will have time to prepare for the danger that awaits them.

All of the above forecasting natural disasters is a leading reflection of the probability of occurrence and development of an emergency based on an analysis of the causes of its occurrence, its source in the past and present. Forecasting consists of different elements. One of them is information about the object of forecasting, which reveals its behavior in the past and present, as well as the patterns of this behavior. But there are also disasters that can behave unpredictably, which makes it difficult to predict the occurrence of this disaster, as well as predict its further behavior after its occurrence.

Disaster predictions methods. Forecasting natural disasters [3] is understood as a scientifically based prediction of their development, nature and scale. The method of forecasting natural disasters should be understood as a method for solving the problem of predicting a specific natural disaster with a certain lead time and using certain initial observational materials. Obviously, as we approach the realization of the predicted phenomenon, i.e., as the lead time of the forecast decreases, its accuracy should increase.

Depending on the waiting time for a natural disaster, forecasts are divided into short-term (less than 12-15 days) and long-term (with greater lead time).

Method – a complex technique, an ordered set of simple techniques aimed at developing a forecast as a whole, a way to achieve the goal, based on knowledge of the most general laws.

Forecasting methods (methods) – a certain set of techniques (methods) for performing forecasting operations, obtaining and processing information about the future based on homogeneous forecasting methods.

Forecasting methodology is a field of knowledge about methods, methods, forecasting systems. Forecasting methodologies were divided into the following categories: foresight, goal setting, planning, programming, design, process development prospects in order to identify problems to be solved.

A forecast development methodology is a selected specific combination of forecasting techniques and methods [10]. A forecasting system ("forecasting system") is an ordered set of techniques and technical means designed to predict complex phenomena or processes.

Forecasting technique – a specific form of theoretical or practical approach to the development of a forecast; one or more mathematical or logical operations aimed at obtaining a specific result in the process of developing a forecast. At the heart of all methods, methods and techniques of forecasting is a heuristic or mathematical approach. The essence of the heuristic approach is to use the opinions of experts. It finds applications for predicting processes that cannot be formalized.

The mathematical approach consists in using the available data on some characteristics of the predicted object, processing them by mathematical methods, obtaining a dependence that connects these characteristics with time, and calculating the dependence of the object's characteristics at a given point in time according to the data.

This approach involves the use of modeling or extrapolation. Forecasting in most cases is the basis for the prevention of natural and man-made emergencies.

In the mode of daily activities, the possibility of natural disasters is predicted – the occurrence of an emergency, its place, time and intensity, the possible scale and other characteristics of the upcoming event.

In the event of a natural disaster, the course of the development of the situation, the effectiveness of certain planned measures to eliminate the emergency, the required composition of forces and means are predicted [9]. The most important of all these forecasts is the forecast of the likelihood of a natural disaster. Its results can be most effectively used to prevent accidents and reduce possible losses and damage in advance.

Comparison of analogues. The first analog is the most interesting program is Natural Disaster Monitor. It shows user in real time where and when emergency events happened, for example earthquakes, tropical cyclones, floods, volcanoes, drought, forest fires. But the program does not show the probability, but only collects data from the site and shows. It just takes data from sate https://www.gdacs.org which is created by United Nations and the European Commission, based on data from international organizations GDACS [4] using JRC tools and algorithms for real-time information exchange. It is interesting idea to use this site which would be help us to predict natural phenomena.

The second analog is Disaster Alert. As a previous analog it also shows to user natural phenomena. But unlike the previous analogue, it shows more information about natural phenomena. It based on PDC which take date from the world and sent user when and where natural phenomena.

The third analog Tropical Storm Risk (TSR). TSR offers a leading resource for predicting and mapping tropical storm activity worldwide. It provides forecasts and information to benefit basic risk awareness and decision making from tropical storms. It helps user to see for the detailed mapping and prediction of tropical storm impacts worldwide.

The four analog is Hurricane Hound. It provides hurricane tracking on a scrollable map and hurricane category, 36-hour forecast, location, distance from current location, max winds, gusts, and time. It helps user to know where hurricane goes and when it would be.

All analogues which were considered have their odds and cons. But they don't predict the natural phenomena they only take information from the international independent open sources about natural phenomena and compare the user's location with a possible disaster.

Implementation. In order to solve the problems of the programs that were given above, we conducted a study and found that the best result is to use a neural network that will help us calculate the percentage of a possible natural phenomenon. For the method of determining natural phenomena will be given below.

A statistical method for calculating the probability of an emergency situation is proposed for implementation. We will consider the following as the main parameters for describing an emergency situation:

- type of emergency situation with the index j assigned to it;
- time interval t for assessing the probability of an emergency occurring;
- estimated number of events N_j for period Δt ;
- event intensity I_j ;
- admissible minimum event intensity threshold L_j .

Therefore any abnormal situation can be represented as a two-dimensional state space with dimensions I_j and N_j . The axis N_j is discrete while I_j is continuous. The measurements of I_j and N_j are not independent and we use the probability density function $d_j\left(I_j,N_j\right)$ to characterize their relationship.

As result the probability of an emergency situation can be represented as a formula:

$$P(t)=\left\{P_1\left(I_1,N_1,t\right),...,P_J\left(I_J,N_J,t\right)\right\}. \qquad (1)$$

According to the above formula, the probability of occurrence of an emergency situation of a certain type can be calculated by cutting the corresponding function $P_j\left(I_j,N_j,t\right)$ on some interval t . Since the cross section is the distribution density of a two-dimensional random variable $d_{j,t}\left(I_j,N_j\right)$, the probability of an event with the expected intensity $L_j \le I_j \le i_{max}$ equals n times in the interval $\Delta t = t - t_0$ can be calculated using the next formula:

$$p_j\left(L_j,i_{max},n,\Delta t\right)=\int_{L_j}^{i_{max}} d_{j,t}\left(i,n\right)di \qquad (2)$$

The main problem of this approach is the large number of parameters in the functions $P_j\left(I_j,N_j,t\right)$. With an increase in the analyzed interval $N_{j,max} \to \infty$ the problem of quantifying the parameters of the function P_j becomes intractable. Also I_j is a time-dependent parameter because $I_{j,N}\left(t\right)\uparrow$, since with increasing Δt the probability of an emergency situation of high intensity increases.

It is possible to optimize solutions to this problem by reducing the time interval Δt to the point where $N_j = 1$. As a result we get rid of the time component in the function P_j .

Therefore, when passing to periods of arbitrary duration $y\Delta t$ and number of events n the task of calculating the probability of occurrence of an emergency situation of a certain type can be expressed by the following formula:

$$d_{n,y} = \frac{y!}{n!\left(y-n\right)!} p_{j,1}^{n}\left(1-p_{j,1}\right)^{y-n} \qquad (3)$$

To solve these problems that are described above was suggested to implement software complex for prediction of different natural phenomena. The program will consist of frontend for simplify interaction with program complex, back-end for grep and execute statistical methods for prediction and database which store statistics data (see Figure 1).

Prediction can be improved by adding neural network [1,8] to our program. It provide possibility to make prediction more flexible and count different points which skipped by pure mathematical methods. For implement software complex with neural network following step should be performed:

- selection of types and architects;
- choose data for training;
- training neural network.

To solve the problem we select perceptron architecture (see Figure 2).

Perceptron architecture – is a linear classifier (binary). And it is used in supervised learning. We

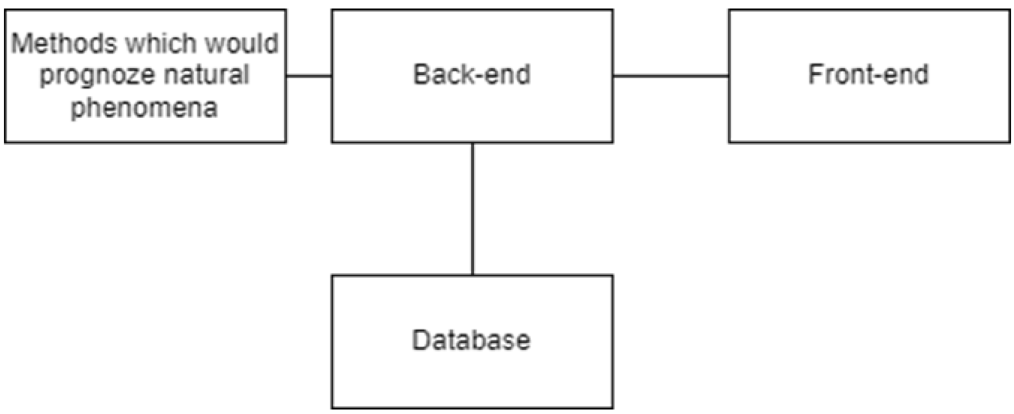

Fig. 1. Program structure

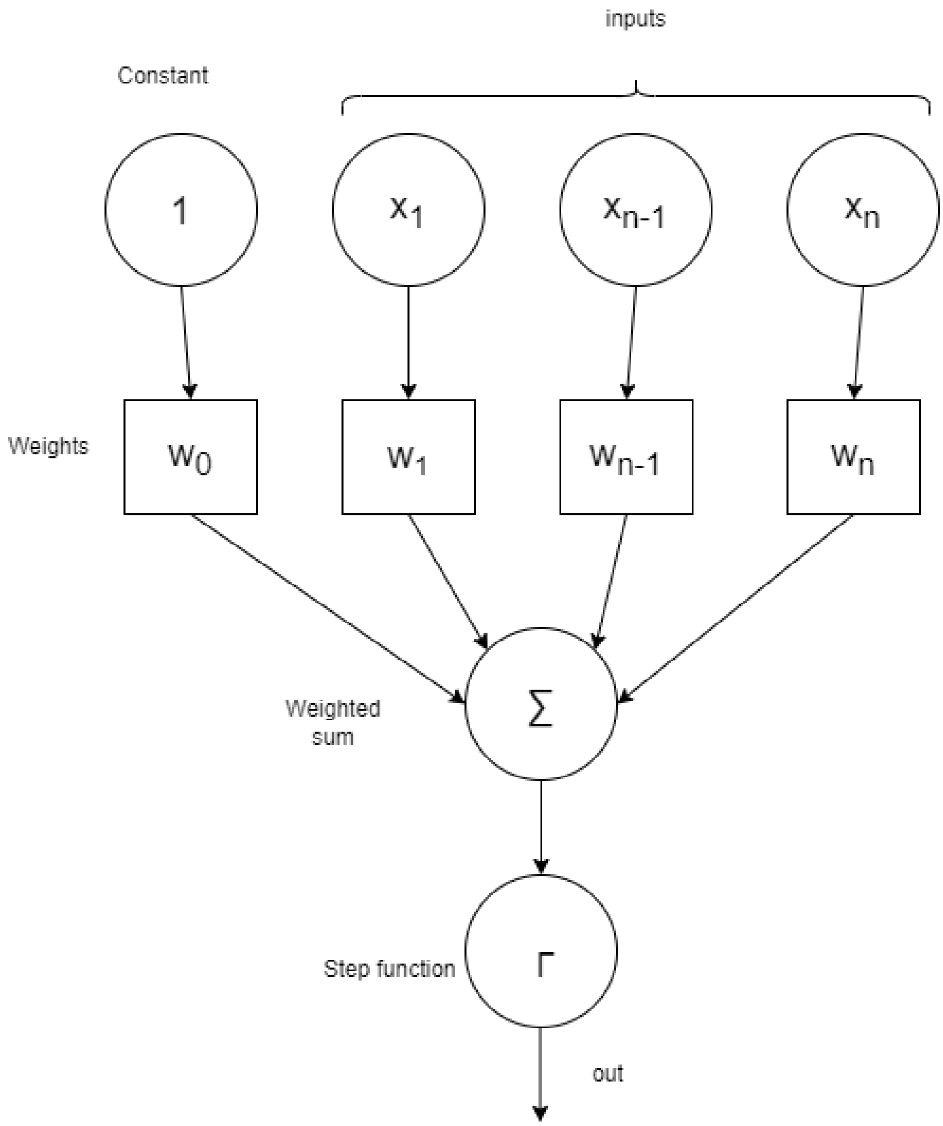

Fig. 2. Perceptron architecture diagram

would use – a multilayer perceptron [2]. Which would help us to see will there be a natural phenomenon. But we also need to teach our neural network. To teach it we would use standard algorithm for reverse error propagation. Propagation the way to move from the Input layer to the Output layer in the neural network. This algorithm is universal and it solving many problems also it has low computational complexity.

In the back end, methods will be implemented that will determine the accuracy of the forecast of the prediction of a natural phenomenon. The database will store users, as well as data needed to determine the accuracy of the forecast of a natural phenomenon. It would be contains user data (Example username, email, password) and forecast data (Example air temperature, wind speed and direction, humidity and precipitation, country and city).

The front-end will represent a user interface where a person can enter data to determine the forecast of a natural phenomenon.

Result. The solution which present in the work would be use neural network and algorithm which help us to predict natural phenomena. Our system would help our user:

- when and where would be natural phenomena;
- how powerful it would be;
- where he can find shelter;
- user would have warning if near would be natural phenomena.

Thus, the system of detecting natural phenomena gives the chance to save live when near starts natural disaster.

Conclusions. This paper represents the general methods and approaches to predicting the occurrence of emergency situations. In particular, the method of statistical forecasting is con-

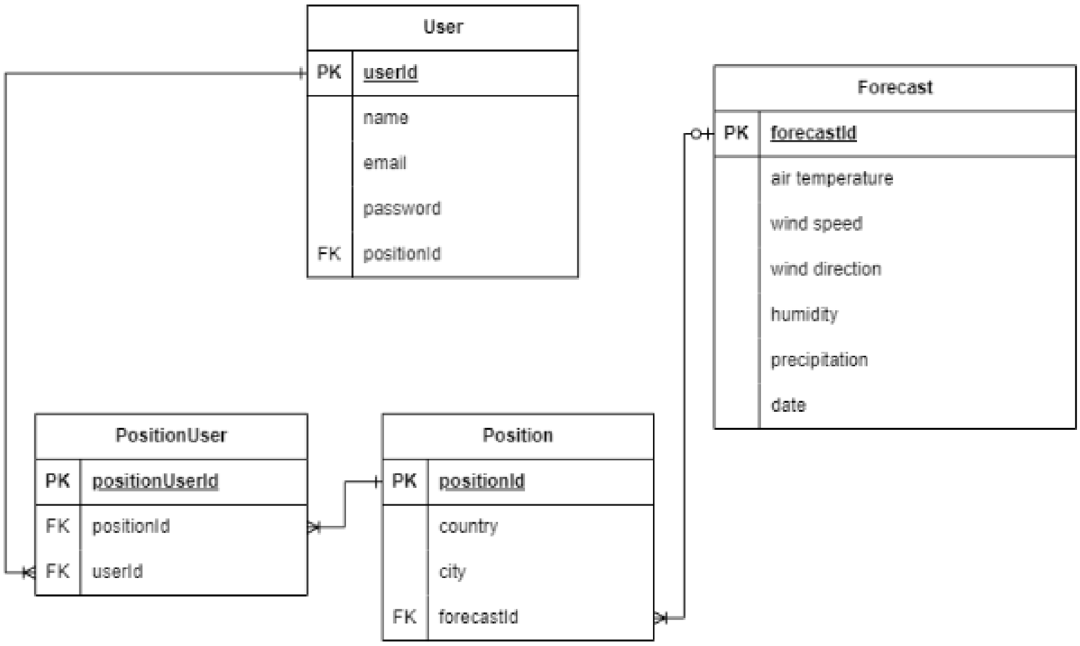

Fig. 3. Database diagram

sidered and a software implementation of the solution of the problem based on this method is proposed. The accuracy and quality of the forecast depend on the detail of the description of emergency situations that have already occurred, but the computational complexity of the solution also increases. Therefore, as one of the optimization methods, it was proposed to introduce a lower event intensity threshold, which makes it possible to discard low-intensity events from consideration as insignificant, thereby reducing computational complexity.

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