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MACHINE LEARNING FOR INTELLIGENT PATTERN RECOGNITION METHODS FOR SEISMIC SAFETY (using earthquake swarms as an example)

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ABSTRACT

The paper presents one of the modern and relevant approaches to using Artificial Intelligence in machine learning, namely, the pattern recognition method. It is one of the powerful tools for intelligent analysis of large volumes of data. Today, there are a huge number of recognition algorithms and technologies for their implementation, including in the processing of seismic data, the use of clustering methods and event recognition in seismology. Such events include weak seismicity (earthquake swarms) in any seismically active region. This approach carries a promising method for representing seismic events in real time, and their visualization occurs directly during the continuous flow of seismic events.

To ensure seismic safety of the region in a timely manner, it is necessary to use modernized methods and means of processing large volumes of data. Including the method of cluster analysis of events in the form of pattern recognition, swarms of weak earthquakes.

Keywords: Machine learning, Artificial Intelligence (AI), intelligent methods, pattern recognition, seismicity, earthquakes, earthquake swarm, seismic safety

SEYSMİK TƏHLÜKƏSİZLİYİNİN TƏMIN OLUNMASI ÜÇÜN MAŞIN ÖYRƏNMƏSİNƏ ƏSASLANAN İNTELEKTUAL ÖYRƏNMƏ ÜSULLARI (ZƏLZƏLƏ KLASTERLƏRİNİN NÜMUNƏSİNDƏ)

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XÜLASƏ

Məqalədə süni intellektin maşında öyrənməsində istifadəsinə müasir və müvafiq yanaşmalardan biri, məhz nümunələrin tanınması metodu təqdim olunur. Bu, böyük həcmli məlumatların intellektual təhlili üçün güclü vasitələrdən biridir. Bu gün seysmik məlumatların emalı, klasterləşdirmə metodlarından istifadə və seysmologiyada hadisələrin tanınması da daxil olmaqla, onların həyata keçirilməsi üçün çoxlu sayda tanınma alqoritmləri və texnologiyaları mövcuddur. Belə hadisələrə istənilən seysmik aktiv regionda zəif seysmiklik (zəlzələ sürüləri) daxildir. Bu yanaşma seysmik hadisələrin real vaxt rejimində təqdim edilməsi üçün perspektivli metod təklif edir və onların vizuallaşdırılması birbaşa seysmik hadisələrin davamlı axını zamanı baş verir.

Regionun seysmik təhlükəsizliyini vaxtında təmin etmək üçün böyük həcmli məlumatların emalının modernləşdirilmiş üsul və vasitələrindən istifadə etmək lazımdır. Nümunələrin tanınması, zəif zəlzələlərin sürüləri şəklində hadisələrin klaster analizi metodu da bura daxildir.

Açar sözlər: Maşın öyrənməsi, Süni intellekt (AI), ağıllı üsullar, nümunənin tanınması, seysmiklik, zəlzələlər, zəlzələ sürüləri, seysmik təhlükəsizlik

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МАШИННОЕ ОБУЧЕНИЕ ИНТЕЛЛЕКТУАЛЬНЫМ МЕТОДАМ РАСПОЗНАВАНИЯ ОБРАЗОВ ДЛЯ ОБЕСПЕЧЕНИЯ СЕЙСМИЧЕСКОЙ БЕЗОПАСНОСТИ (НА ПРИМЕРЕ РОЕВ ЗЕМЛЕТРЯСЕНИЙ)

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АННОТАЦИЯ

В работе представлен один из современных и актуальных подходов использования Искусственного Интеллекта в машинном обучении, а именно, метод распознавания образов. Он является одним из мощных средств интеллектуального анализа больших объемов данных. На сегодняшний день существует огромное количество алгоритмов распознавания и технологий их реализации, в том числе при обработке сейсмических данных, использования методов кластеризации и распознавания событий в сейсмологии. К таким событиям можно отнести слабую сейсмичность (рой землетрясений) в любом сейсмоактивном регионе. Такой подход несет в себе перспективный метод представления сейсмических событий в реальном времени, а их визуализация происходит непосредственно в ходе непрерывного потока сейсмических событий.

Для своевременного обеспечения сейсмической безопасности региона, необходимо использовать модернизированные методы и средства обработки больших объемов данных. В том числе метод кластерного анализа событий в виде распознавания образов, роев слабых землетрясений.

Ключевые слова: Машинное обучение, Искусственный Интеллект (ИИ), интеллектуальные методы, распознавания образов, сейсмичность, землетрясения, рой землетрясений, сейсмическая безопасность

INTRODUCTION

At the present stage of development of artificial intelligence (AI) methods, the pattern recognition algorithm is being developed and improved as one of the AI methods. There are various methods used for pattern recognition [1,2, 3, 4 , 5-8]. Modern recognition methods include the pattern recognition algorithm based on graphical clustering of data (using the example of earthquake swarm’s recognition), since the seismicity of the study region acts as data for their clustering. In recent years, pattern recognition has become one of the relevant areas related to the automation of information processing and use. In this direction, certain successes have been achieved in solving theoretical and practical problems [1-23]. Pattern recognition technology remains relevant today [8]. The paper presents the main theoretical and practical issues of applying the pattern recognition algorithm based on the graphical clustering method (GCM) of data - using earthquake swarms as an example, and an attempt is made to assess the prospects for its development and application in machine learning [13-15].

Research methodology

As is known, pattern recognition (objects, signals, situations, phenomena or processes) is the task of identifying an object or determining any of its properties based on its image or other characteristics. In this case, the data in the computer is a set of objects, which is represented by a set of unique elements of the same type. An image is a classification grouping that unites (highlights) a certain group of objects based on a certain feature. Images have characteristic properties. The method of assigning an element to a certain image is called a decision rule. A metric is a way of determining the distance between elements of a universal set. The smaller this distance, the more similar are the objects that we recognize [8]. According to the materials of the Internet "Wikipedia", the concept of a metric is understood as: A metric on a set X is a mapping $d\colon X\times X\to\mathbb{R}$ that assigns to each pair $(x,y)\in X\times X$ a real number $d(x,y)$ that satisfies the following conditions: 1) non-negativity: $d(x,y) \geq 0$ for any (x,y). 2) $d(x,y)=0$ if and only if $x = y$. 3) symmetry: $d(x,y)=d(y,x)$. 4) triangle inequality: $d(x,y) \leq d(x,z)+d(z,y)$ for any $x,y,z \in X$. X The set together with the mapping d is called *a metric space*, and is denoted by (X,d). The metric is a generalization of the concept of *distance* to arbitrary spaces. Any space can be provided with a metric.

Setting and solution method

One of the areas of application of AI methods in seismic research is the pattern recognition method. This method uses procedures of intelligent analysis and graphical clustering of events. Based on the formal features of certain seismic events, a seismologist can formulate the stages of recognition of these events and provide AI with a means of a formal procedure for identifying the object that should be recognized in a large flow of seismic events. Machine learning is based on the description of the procedure for recognizing specific seismic objects according to their criteria. Step-by-step machine learning is built from several stages of intelligent data processing.

The following approach is used in the seismic data stream recorded continuously during seismicity monitoring of the study region.

The recognition procedure can be described as follows:

1. From a continuous stream of seismic events, a portion of events (data) is loaded.
2. In this portion of data, the clustering (sampling) procedure is considered.
3. If clustering is successful, then seismic events selected according to specific criteria are allocated to a specific catalog of recognized earthquake swarms.
4. Recognition criteria describe the relationship between seismic events by distance, time between events, and the number of events within a certain radius.
5. Based on the generated catalog of recognized seismic events, a graphical visualization of the swarm activity of the study region is constructed.

That is, machine learning is reduced to specific recognition and visualization of swarm activity in a region and the identification of promising areas of seismic activation in real time. Computer modeling in this case complements the seismicity monitoring maps of the region as a whole, with specific zones of swarm clusters and can be used as interactive zones for observation and monitoring of the pattern of seismicity activation in the region [9-14, 16-23] .

Such maps contain information about the current seismic state of a seismically active region and can be used in further research to ensure seismic safety of the region.

The cluster analysis method has been tested and is used in the laboratory of physics of geodynamic and seismic processes. The author of the earthquake swarm recognition algorithm has a master's degree in engineering and technology, so he can safely call himself an expert in this field . More information about the swarm recognition method can be found in publications [16-20]. Machine learning implementation requires highly qualified specialists in programming and modern software. The machine learning complex should include high-speed Internet for uninterrupted receipt of seismic data from Internet sources. The Intelligent Shell should include easily configurable and understandable software packages for various procedures. Namely, a complex for monitoring the current seismicity of the region, according to reliable seismic catalogs. Visualization of such seismic events can serve as an initial data set for clustering. The graphical clustering method is the main method in the procedure for recognizing earthquake swarms. The graphical data clustering method for pattern recognition (using earthquake swarms recognition as an example) is universal in various applied recognition problems. The paper considers issues of recognizing earthquake swarms based on graphical data clustering in any seismically active region. The results of applying the specified recognition algorithm showed that graphical clustering of data is most convenient for recognizing swarm patterns in the seismicity of a region [15], and numerical characteristics of swarms were also obtained.

Formal description of machine learning

Thus, the basis of the machine learning algorithm and the method for identifying swarm sequences of events is such a theoretical approach.

Let's a (1,1), a (1,2), ..., a (N N) occurs in a limited area during time t_i. Each of these events is characterized by a set of parameters, some of which may be repeated (coordinates, magnitude, etc.), while others never repeat.

It is always possible to construct a matrix R of states (1), symmetric with a zero diagonal (keeping in mind that in the general case the matrix R can be multidimensional) [14].

$$\mathrm{R} = \begin{bmatrix} a_{11} a_{12} .. a_{1N} \\ a_{21} a_{22} .. a_{2N} \\ .... \\ a_{N1} a_{N2} .. a_{NN} \end{bmatrix} (1)$$

According to generally accepted methods of cluster analysis, we must analyze the correspondence of the elements of the rows in (1) to the given rules.

We believe that if there is a spatial relationship and interdependence of events, then it should be expressed through "distances" (Euclidean or other) between events in n - dimensional space.

If the geographic coordinates of an event are known, then we select the geometric distance between the epicenters of earthquakes as a measure of the relationship.

Considering that the most interconnected events are those for which the inter-epicentral distances are minimal.

After determining the compliance of the matrix elements (1) with a given rule in a given parameter space (for example, the distance between events), we plot them on a graph and connect them with lines in the sequence following from (1).

If there is a relationship and interdependence of events in the matrix (1), related tree-like structures are formed on the graph.

The nodes of each of these trees form clusters similar to those calculated by other cluster analysis methods. MGC does not require additional mathematical operations for clustering, and therefore is performed significantly faster than other cluster analysis methods.

The calculation time for the MGC is proportional to the number of events in the sample that forms the matrix (1).

The advantage of the MGC is that intersecting subsets are allowed in the analyzed state space.

Such situations may arise when analyzing time sequences of events, when there are clusters whose lifetime is less than the interval of the entire sample.

Features of the recognition algorithm. First, we defined the numerical characteristics of "swarms" as earthquake sequences suitable for their description and recognition of swarms in the catalog. This seems important because objective criteria for recognizing and identifying "swarms" were not known. In general, the process of "swarm" formation can be identified with the procedure of spatial grouping of seismic events. For a more detailed qualitative analysis of swarms, see [14,1 6-20].

Results

The presented method of graphical clustering of data is proposed to carry out recognition of earthquake swarms in the seismically active study region.

Theoretical justifications are proposed and a method for recognizing “earthquake swarms” is described, as well as a step-by-step practical algorithm for their recognition is described.

An important result for machine learning is the Earthquake Swarm Recognition Criteria:

– the number of earthquakes in the “swarm” N≥3;
– spatial distance between adjacent events forming a “swarm” L≤10' in angular measure;
– time between events in the "swarm" 0<Tm≤15-26 days.

Using these numerical constraints, machine learning and MHC calculations are performed.

A catalogue of swarms is then compiled for the selected area.

Conclusion

The introduction of machine learning into the process of studying the seismicity of any region will allow obtaining interactive catalogs of swarm events. Mapping of earthquake swarms will be done online, which will allow timely monitoring of seismic safety of areas ready for the occurrence of strong earthquakes.

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