Journal of the Georgian Geophysical Society, e-ISSN: 2667-9973, p-ISSN:1512-1127
Physics of Solid Earth, Atmosphere, Ocean and Space Plasma, v. 27(1), 2024, pp. 36 - 41

On the Potential of Geospatial Artificial Intelligence - GeoAl in Solving Problems of Development of Metal-Bearing Technogenic Deposits

[1]Gigo V. Jandieri, [2]Inga S. Janelidze, [3]Onise B. Zivzivadze, [4]Giorgi G. Loria

[1] Independent Researcher, Leipzig, Germany
[2]Georgian Technical University Tbilisi, Georgia
[3]Akaki Tsereteli State University, Kutaisi, Georgia
[4]Georgian Aviation University, Tbilisi, Georgia
[1]e-mail: gigo.jandieri@gmail.com; [2]e-mail: ingajanelidze9@gmail.com;
[3]e-mail: onise.zivzivadze@gmail.com; [4]e-mail: giorgiloria1979@gmail.com

ABSTRACT

Solid mineral wastes generated as a result of mining and processing of minerals represent a significant environmental problem of the geosphere. Their accumulations in terms of scale and content are deservedly referred to technogenic deposits, the development of which is of great interest both for modern and upcoming digital-industrial revolution called "Industry-4.0". It is noted that the effectiveness of this activity will depend on the efficiency and adequacy of the assessment of the environmental and economic feasibility of extracting the target components, on the quantitative assessment of the volume of accumulation of the extracted element, the possibility of extending its life cycle, on the expected composition of by-products and their consumer value, on the minimum acceptable level of profitability of the selected development technology, as well as - on the rate of re-accumulation and environmental inertness of the waste generated during recycling. In connection with the above, this study emphasizes the importance and necessity of the application of modern hybrid geospatial artificial intelligence (GeoAI), which includes the synergy of general artificial intelligence (AI) based on adaptive neuro-fuzzy inference system (ANFIS) with geographical information systems (GIS). Consequently, in order to increase the efficiency of GeoAI application and to obtain accurate and effective results in solving the set tasks, it is recommended and justified the expediency of combining the knowledge of neural networks and fuzzy logic with GIS data, where the latter will serve as a source-storage of reference (initial/boundary) data on the current and desired for achieving the set goal changes in the developed technogenic deposits.

***Key words**: ecology of the geosphere, technosphere, secondary resources, GeoAI, Industry-4.0.*

Introduction

It is known that geospatial artificial intelligence (GeoAI) is a hybrid of artificial intelligence (AI) and geographic information system (GIS) with inherent spatial data and geospatial analysis technologies, the purpose of which is to adequately identify spatial problems accumulating in the technosphere and search for optimal options for their successful solution [1]. GeoAI functionality also includes the use of spatially oriented artificial intelligence methods [2], based on the adaptive neuro-fuzzy inference system (ANFIS) [3], which is designed to solve spatial problems through the analysis of spatial data and includes methods for detecting patterns, making forecasts, spatio-temporal forecasting of upcoming/expected changes, etc.

GeoAI can play a critical role in solving spatial problems across a wide range of application areas. An important aspect of GeoAI is the application of traditional artificial intelligence methods in obtaining spatial data by extracting, classifying and discovering information from/in structured and unstructured data. This data includes tabular data, remote sensing data (including rasters, images, lidar point clouds, video, and others), and even text data. When obtaining spatial data, it is necessary to solve problems such as searching and organizing objects in images, creating 3D data using lidar, or extracting location information from unstructured text for subsequent geocoding [4].

Another key aspect of GeoAI is the application of machine learning and deep learning techniques, including spatial statistical methods and machine learning techniques, to analyze spatial data for applications such as spatial pattern detection and forecasting, including spatiotemporal forecasting. Using new machine learning and deep learning tools with spatial data gives practitioners new opportunities to explore complex problem spaces. Using machine learning techniques on spatial data, as well as incorporating spatially-aware models that incorporate some geographic aspects (location, shape, proximity, etc.) directly into the forecasting algorithm, can not only make the models more efficient, but also more accurate. reflecting the reality that they are trying to model. These methods can be used to allocate, conserve, or exploit mineral natural or secondary resources based on meaningful spatial patterns, to identify trends and anomalies in space and time, and to incorporate spatial relationships into forward-looking planning processes.

Based on the above, it is indisputable that GeoAI can play a vital role in solving optimization problems related to the formation, conservation or development of deposits of technogenic origin that are harmful to the geosphere. Therefore, assessing the state of development, deep learning and effectively exploiting the potential of GeoAI seems to be a very urgent task.

Features of the formation of technogenic deposits and the role of GeoAI in their management

Solid mineral waste, as a rule, is formed due to a discrepancy between the composition of the subsoil and the needs of society. They can be divided into mining waste (overburden) and mineral processing waste (tailings). The amount of mineral waste generated mainly depends on the characteristics of a particular deposit: the conditions of occurrence of the mineral, the method and technology of development, the content of the useful component, enrichment technologies, etc. Waste generated as a result of mining or processing of minerals is stored using special storage facilities. Since these can be quite large formations containing under-extracted mineral components, the term "technogenic deposits" was introduced in many countries of the world, including Georgia [5]. This means that under certain conditions (for example, after a change in the degree of conditionality), it becomes advisable to selectively extract minerals from these accumulations of mineral mass on an industrial scale [6].

As a rule, technogenic deposits are represented by two types of objects: dumps and tailings dumps. The former is formed due to the accompanying extracted rock mass, the latter are waste from pyro - or hydrometallurgical processing of primary mineral raw materials. Accordingly, they differ from each other in mineralogical and granulometric composition. According to the possibilities of use, solid mineral waste can be divided into three groups: waste for which there are no technologies for their processing or the volume of their formation exceeds the needs of the economy for this type of resource; waste for which processing technologies are available, but production capacity is insufficient; waste that is secondary raw materials and included in material balances, but not yet used by enterprises.

The most significant ways to reduce the scale of accumulation of mineral waste include: reclamation of dumps and tailings, use of waste to fill mined-out space, recycling of depleted technogenic raw materials, as well as additional extraction of useful components present in waste [7, 8].

The primary role of GeoAI in the management of marked technogenic mineral accumulations is to identify them, map them, inventory them, assess the degree of their growth/decrease and the actual impact on the environment, in order to prevent possible environmental disasters. This is especially true for tailings ponds of ore processing plants, where large quantities of sludge with a high-water content accumulate, the safe retention of which requires the construction of especially expensive reinforced dams. For Georgia, such objects that are in dire need of servicing GeoAI systems are the Gurgumel tailings dump of the Chiatura manganese mining and processing plant [9] and the tailings of the Kazretsky complex RMG-Cooper, which mines gold and copper [10].

Features of the environmental and economic impact of technogenic deposits and the possibility of their mitigation using GeoAI

The negative impact of these storage facilities on the environment occurs mainly in the following areas: pollution of the atmosphere surrounding the facility, surface and underground water bodies, and soil. Substances released by these objects may have toxic or radioactive properties. In addition, in some places the height of mineral mass storages can reach 100 meters or more, which contributes to changes in the wind regime and, accordingly, the climatic conditions of the area. A significant mass of stored substance puts pressure on the surface of the earth and can lead to changes in the hydrogeological regime. Accumulated dumps and tailings ponds occupy large areas, thereby removing potentially useful lands from circulation. For enterprises, these environmental problems result in increased tax payments for negative impacts on the environment [11].

The peculiarities of the influence of the process of accumulation and exploitation of technogenic deposits on mining and metallurgical production is that enterprises are forced to bear certain costs, while receiving additional products and economic results. In particular, the costs of utilization or recycling of technogenic deposits are formed by costs associated directly with the extraction, transportation, processing of mineral mass and the sale of the resulting finished product. At the same time, positive economic results should include income from the sale of additional products, a reduction in environmental damage, a reduction in the costs of disposal and maintenance of mineral waste and reclamation costs, a reduction in payments for the disposal of solid waste into the environment and for the withdrawal of land suitable for agricultural land [12]. Along with the positive environmental effect, there is also a negative one associated with technological processing processes. It occurs during mining, enrichment processing, transportation of rocks, enrichment tailings or metallurgical slag. During the development of the noted technogenic deposits, the area of withdrawn land may temporarily increase, and the number of emissions into the atmosphere and aquatic environment may increase [13]. It is here, to control and prevent random (unforeseen) environmental violations, that the first need arises for the use of GeoAI, which includes the synergy of general artificial intelligence (AI), adaptive neuro-fuzzy inference system (ANFIS) and geographic information systems (GIS) with human intelligence [14], authorized to make decisions.

Based on the above analysis, it follows that the development processes of the mentioned fields require dynamic optimization in real operating time, both from the point of view of increasing technical and economic and environmental efficiency. Solving optimization problems with dynamically changing input parameters is not possible without the use of the modern hybrid intelligent system GeoAI. Here GeoAI can certainly play a key role, both in monitoring and managing the processes of accumulation and targeted consumption (recycling) of technogenic raw materials. In this case, data obtained from GeoAI can serve as a generator of confirmed reference information for solving problems of mitigating the overall environmental load, including minimizing land taken out of production and reducing the impact on adjacent above-ground and underground water bodies. Based on the noted data, decisions made on the general feasibility of developing a specific technogenic deposit, on the quantity and degree of extraction of the components contained in it and their beneficial use, should be based on a summary environmental and economic assessment that takes into account all of the above factors.

In this case, the criterion for environmental and economic assessment of the degree of development of technogenic deposits used in GeoAI must satisfy the following basic conditions: take into account all the main costs associated with the utilization of technogenic raw materials and the technical results obtained; do not contradict various environmental indicators of production; not violate the maximum permissible standards for the emission (discharge) of associated mineral or chemical formations and fully reflect the benefit of these decisions for the interested party, i.e. the owner of the technogenic deposit. The last condition is justified by the fact that the process of using technogenic deposits is most often internal to a typical mining and metallurgical enterprise and is carried out at its own expense. Therefore, the assessment does not require comparison of its efficiency with competitive production processes at other enterprises and should be made according to internal indicators. This methodology is carefully described and algorithmized in the study [8], where, using the example of manganese-containing industrial waste, a solution to the problem of their highly efficient, economically break-even internal recycling is proposed.

The criterial framework developed in this way will make it possible to create on its basis new mathematical models suitable for training GeoAI. The created economic and mathematical models must include a target function, by value, which selects the optimal technical and economic solution and a number of boundary (ecological) conditions necessary for the objectivity of decision-making and reducing the duration of the estimated time.

Such boundary conditions include: the total amount of technogenic mass in dumps and tailing dumps planned for targeted use; annual amount of utilised technogenic mass; the amount of contained components extracted during the disposal of solid mineral waste (degree of conditionality), the degree of extraction of each component, the potential for replacing mined ore (Ore Substitution Index), the long-term scale of extending the life cycle of existing mines and quarries, etc. As a current indicator of the degree of useful use, it is recommended to take the coefficient of use of mineral mass, which is the ratio of the amount of mineral mass extracted from a technogenic deposit to the volume of products obtained as a result of metallurgical restoration of this mass. It should also be noted that when determining the number of extracted components, one should be guided not only by their value, but also by the scale (volume) of their recycling, which is very important for mitigating the anthropogenic load on the environment.

Conclusion

Carried out using geospatial artificial intelligence -GeoAI, the collection of geospatial information and dynamic observation data of technogenic deposits and adjacent lands, combined with environmental, socio-economic and other statistical data, will provide authorized decision-making bodies with a unique digital contribution to preparation and monitoring and assessing the effectiveness of the chosen policy for the re-development and use of accumulated secondary metal-containing resources. The scale of the formed digital portfolio, along with digital developments and industry innovations of the fourth industrial revolution "Industry 4.0" will play a decisive role in the global management of technogenic accumulations, allowing humanity to take timely, more accurate and environmentally softened, biosphere-friendly steps in the development of the technosphere.

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გეოსივრცული ხელოვნური ინტელექტის (GeoAI) პოტენციალის შესახებ ლითონშემცველი ტექნოლოგიური საბადოების დამუშავების პრობლემების გადაჭრისათვის

გ. ჯანდიერი, ი. ჯანელიძე, ო. ზივზივაძე, გ. ლორია

რეზიუმე

სასარგებლო წიაღის მოპოვებისა და გადამუშავების შედეგად წარმოქმნილი მყარი მინერალური ნარჩენები მნიშვნელოვან ეკოლოგიურ საფრთხეს უქმნიან გეოსფეროს. აღნიშნული ანთროპოგენული წარმონაქმნები, თავისი მასშტაბებისა და შემცველობის მიხედვით, დამსახურებულად კლასიფიცირდება როგორც ტექნოგენური საბადოები, რომელთა სასარგებლო გადამუშავებაც, როგორც თანამედროვეობის, ასევე - ინტენსიური ფორმირების სტადიაში მყოფი «Industry 4.0» სახელით ცნობილი მეოთხე ინდუსტრიული რევოლუციისშემდგომი პერიოდისათვისაც ერთ-ერთი პრიორიტეტული ამოცანა იქნება. სტატიაში გამოკვეთილია აღნიშნული ანთროპოგენული აქტივობის ეფექტურობის ამაღლების შესაძლებლობა ფასეული კომპონენტების მეორადი მოპოვების ეკოლოგიური და ეკონომიკური მიზანშეწონილობის კომპლექსური შეფასების გზით. მათ შორის ხაზგასმულია ისეთი კრიტერიუმების გათვალისწინების აუცილებლობა, როგორებიცაა მიზნობრივი ელემენტების აკუმულირებისა და მათი სასიცოცხლო პერიოდის შესაძლო გაფართოების მასშტაბები, გადამუშავებისას წარმოქმნილი თანმდევი (არამიზნობრივი) პროდუქტების ქიმიურ-მინერალური შემადგენლობა და მათი სამომხმარებლო ფასეულობა, გადამუშავებისათვის შერჩეული ტექნოლოგიის რენტაბელობის მინიმალური დასაშვები ზღვარი, და ბოლოს, - გადამუშავებისას ემისირებული ნარჩენების ეკოლოგიური უვნებლობის ხარისხი. შესრულებული ანალიზის საფუძველზე, დასახული მიზნის მისაღწევად შემოთავაზებულია

ისეთი ჰიბრიდული გეოსივრცითი ხელოვნური ინტელექტის (GeoAI) შექმნა და გამოყენება, რომელიც დაფუძვნებული იქნება ადაპტირებულ ნეირო-არამკაფიო სისტემის (ANFIS) ფუნქციონირების პრინციპით შექმნილი ხელოვნური ინტელექტის (AI) და გეოგრაფიულ ინფორმაციულ სისტემების (GIS) სინერგიაზე, სადაც ეს უკანასკნელი შეასრულებს მიზნობრივ ტექნოგენურ საბადოში, მისი დამუშავებისას მიმდინარე ფაქტობრივი და დაგეგმილი ცვლილებების შესახებ ანალიტიკურ მონაცემებთა ბაზის ფორმირებისა და ხელოვნური ინტელექტის ნეიროქსელებში მოთხოვნისამებრ მიწოდების ფუნქციას.

საკვანძო სიტყვები: გეოსფეროს ეკოლოგია, ტექნოსფერო, მეორადი რესურსები, GeoAI, ინდუსტრია-4.0.

О потенциале геопространственного искусственного интеллекта - GeoAl для решения задач разработки металлсодержащих техногенных месторождений

Г. Джандиери, И. Джанелидзе, О. Зивзивадзе , Г. Лория

Резюме

Твердые минеральные отходы, образующиеся в результате добычи и переработки полезных ископаемых, представляют собой существенную экологическую проблему геосферы. Их скопления по масштабам и содержанию заслуженно относят к техногенным месторождениям, разработка которых представляет собою большой интерес, как для современной, так и — предстоящей цифрово-промышленной революции, называемой «Индустрией-4,0». Отмечено, что эффективность данной деятельности будет зависеть от оперативности и адекватности оценки эколого-экономической целесообразности извлечения целевых компонентов, от количественной оценки объема накопления извлекаемого элемента, возможности расширения его жизненного цикла, от ожидаемого состава получаемых побочных продуктов и их потребительской ценности, от минимально допустимого уровня рентабельности выбранной технологии разработки, а также — от темпов повторного накапливания и экологической инертности образующийся при повторной переработке отвальных отходов. В связи с отмеченным, в данной исследовании, подчеркнута важность и необходимость применения современного гибридного геопространственного искусственного интеллекта (GeoAI), включающее в себя синергию общего искусственного интеллекта (ИИ), основанной на адаптивной системе нейронечеткого вывода (ANFIS) с географическими информационными системами (GIS). Следовательно, для повышения эффективности применения GeoAI и получения точных и эффективных результатов в решении поставленных задач, рекомендовано и обосновано целесообразность объединения знаний нейронных сетей и нечеткой логики с данными GIS, где последний будет служить в качестве источника-хранилища опорных (исходных/граничных) данных о текущих и желаемых для достижения поставленной цели изменениях в разрабатываемом техногенном месторождений.

Ключевые слова: экология геосферы, техносфера, вторичные ресурсы, GeoAI, Индустрия-4,0.