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DEVELOPMENT OF AN EFFICIENT DATABASE FOR GEOPHYSICAL AND SURVEYING MONITORING FOR THE GEODATA ZONES SYSTEM

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Abstract. This article delves into the development of an advanced database aimed at integrating and analyzing geophysical and surveying data within the GeoDATA Zones monitoring system, specifically tailored for quarry applications. Modern mining operations face significant risks such as landslides, collapses, and other geological hazards due to inadequate data management practices. The GeoDATA Zones system addresses these challenges by implementing innovative data processing methods using machine learning and artificial intelligence algorithms. This article's primary goal is to showcase how the development of a structured database can improve the speed, accuracy, and reliability of geophysical and surveying data analysis, which in turn supports more effective decision-making processes.

Key factors influencing the stability of rock masses, including geological formations, physical properties of rocks, fracturing, and the impact of ongoing mining activities, are thoroughly explored. The article also examines environmental influences, such as water saturation and seismic activities, which can further destabilize rock structures. Furthermore, the article highlights the critical role that a well-structured database plays in ensuring data integrity, security, and scalability, while also enabling integration with other systems utilized in the mining sector. The database design considers logical and physical structures, with Microsoft SQL Server being the primary database management system. Additionally, visualization tools such as Power BI are leveraged to enhance data interpretation, analysis, and reporting capabilities for real-time decision-making.

The development process incorporates robust security measures, including multi-level user authentication, data encryption, and access control protocols to safeguard against unauthorized access and ensure the system's resilience. Research findings suggest that GeoDATA Zones can significantly improve the efficiency, safety, and sustainability of mining operations, thereby contributing to the long-term success of mining enterprises. This solution fosters proactive decision-making and risk mitigation, aligning with the industry's push toward more sustainable and environmentally conscious mining practices.

Keywords: geophysical condition, rock mass stability, database management, void detection in rock formations, machine learning, mining safety, data integration, sustainable mining practices.

1. Introduction

In modern mining, significant attention is paid to effective data management related to the stability of rock masses. Monitoring systems such as GIS Terra Mining, MineScape, and RockWare are critical for ensuring the safety of mining operations, as they enable comprehensive analysis of the condition of rock masses through geological and surveying data. The importance of these systems is underscored by the need for timely detection of potential risks such as landslides and collapses, which could endanger worker safety and affect the efficiency of extraction operations.

The primary goal of this article is to develop an effective database for integrating and analyzing surveying and geophysical data within the GeoDATA Zones monitoring system for quarries. This task is becoming increasingly relevant due to the need to use modern digital technologies for the collection, processing, and analysis of large and continuously expanding datasets. The development of a structured database will improve the speed and accuracy of analysis, as well as support informed decision-making regarding the management of quarry stability.

The article examines the key factors affecting the stability of rock masses, including geological structure, physical properties of rocks, the seismic impact of drilling and blasting operations, as well as the influence of mining excavations. An analysis of data collection methods is conducted, particularly surveying and geophysical methods, which provide a comprehensive approach to studying quarry conditions [1–10].

This article also highlights the significance of utilizing machine learning and artificial intelligence algorithms to enhance data processing efficiency and predict potential threats. In addition, it emphasizes the importance of ensuring data security, scalability, and the ability to integrate with other systems used in the mining industry.

Thus, the development of a database for the GeoDATA Zones system will make a significant contribution to improving the efficiency and safety of mining operations and will also lay the groundwork for further research and development in this field.

2. Methods

Development of an effective database for the GeoDATA Zones system is a key step in ensuring reliable and accurate collection, processing, and analysis of geophysical and surveying data. This system aims to integrate various data to improve the efficiency of geoengineering research in managing mining processes. This section of the article discusses the methods and tools that will be used to create the database.

Structural analysis of the database involves determining the optimal architecture that ensures the integrity, reliability, and scalability of the system. The main components of the GeoDATA Zones database include:

– Entities *and attributes:* Defining the main entities, such as geophysical data, surveying data, monitoring zones, data on mine workings, and others. Each entity has a set of attributes that describe its characteristics and properties.

– Relationships *between entities:* Defining the relationships between different entities to ensure data integration and interaction. This includes establishing one-to-many and many-to-many relationships, allowing the integration of various data types into a single system.

– Data *hierarchy:* Creating a hierarchical data structure that enables efficient organization and management of information. This includes classifying data by type, importance level, and other characteristics.

– *Data indexing:* Developing indexes for quick access to data, ensuring optimal system performance during queries and analysis.

The process of developing the database for GeoDATA Zones includes several stages to ensure its reliability and efficiency:

1. Requirements analysis:

– Collecting requirements: Identifying user needs and specifications for the database, including data types, volume of information, and security requirements.

– Analysis of existing systems: Reviewing similar solutions to determine best practices and avoid potential issues.

2. Database design:

– Logical design: Creating a conceptual model of the database, which includes defining entities, attributes, and their relationships.

– Physical design: Developing the physical structure of the database, including selecting the type of DBMS (database management system), determining the data storage format, and optimizing the structure.

3. Database implementation:

- Selecting a DBMS: Choosing the optimal database management system (e.g., PostgreSQL, Microsoft SQL Server, Oracle) that meets the needs of the GeoDATA Zones system.
- Creating tables and relationships: Implementing the database structure in the selected DBMS, including creating tables, defining relationships, and establishing constraints to ensure data integrity.

4. Integration and testing:

- Data integration: Selecting methods for user data input into the GeoDATA Zones system.
- Testing: Conducting database testing to identify and correct possible errors, as well as to verify its performance, security, and functionality.

5. Ensuring data security:

- Authentication and authorization: Implementing mechanisms for controlling access to the database, including user authentication and defining access rights.
- Backup: Setting up backup and data recovery procedures to prevent data loss in case of emergencies.

6. Scalability and optimization:

- Query optimization: Applying optimization techniques to improve query performance and reduce system response time.
- Scalability: Ensuring the database can be expanded without losing performance, allowing it to handle increasing volumes of data.

Various tools and technologies will be used for database development and maintenance:

- SQL (Structured Query Language): Used to manage data in relational databases, including creating tables, relationships, and executing queries.
- ETL (Extract, Transform, Load): Tools for extracting, transforming, and loading data from different sources into a single database.
- Visualization tools: Tableau, Power BI for creating interactive visualizations and reports based on data from the database.

3. Theoretical part

The GeoDATA Zones system represents a comprehensive approach to managing and analyzing geophysical and surveying data, which are critically important for ensuring safety and controlling the efficiency of mining operations. The foundation of this system's development lies in creating a reliable and scalable database that allows the integration of various data and provides real-time access to them.

Integration of geophysical and surveying data.

The integration of geophysical and surveying data is one of the key aspects of the GeoDATA Zones system. This approach ensures a comprehensive assessment of rock mass stability and the identification of potential risks. Such integration includes:

- Combining data from different sources: This includes seismic survey data, GNSS measurements, the presence of mine workings within specific zones, hydrogeological, and geological data.

– Intelligent analysis of research results to assess the impact on mining safety: Machine learning and artificial intelligence algorithms are used for data analysis and predicting potential risks. This allows evaluating the impact of various factors on the stability of rock masses and developing risk mitigation strategies, which ensures the safety of mining operations. This approach enables the timely identification of potential threats and the development of appropriate preventive measures.

The GeoDATA Zones system uses a general data structure approach that includes normalization to ensure data integrity and reduce redundancy, as well as indexing to optimize data access speed. The relational model allows for the effective integration of data from various sources, ensuring logical organization and ease of access to information.

Data security methods.

Data security is a key aspect in the development of the GeoDATA Zones database. This includes:

– Access control: Using authentication and authorization to manage user access to the system.

– Backup: Regular creation of data backups to protect against data loss in the event of emergencies.

Using Microsoft SQL Server.

Microsoft SQL Server is the primary tool for implementing the GeoDATA Zones database due to its numerous advantages:

– Support for large volumes of data: SQL Server can handle large volumes of data, which is critically important for the mining industry.

– Integration with other tools: Easy integration with Power BI, Excel, and other products for data analysis and visualization.

– Geospatial capabilities: Support for geospatial data, allowing for work with maps and geographic information.

– High security: Features such as encryption, access control, and other security functions ensure data protection.

Application of theory in practical implementation.

The development of the GeoDATA Zones system is based on theoretical principles of geophysical data integration and processing, which allows for:

– Improving monitoring efficiency: Ensuring real-time access to relevant data and the ability to analyze them in real-time.

– Enhancing the safety of mining operations: By identifying potential risks and threats, in each studied zone of the quarry field, the GeoDATA Zone system allows for situation control through the development and implementation of safety measures, which are designed and implemented by system users and the working staff of the enterprise and subcontracting organizations.

4. Results

In the GeoDATA Zones system, several key user roles have been defined, each playing an important part in ensuring the effective monitoring and management of quarries. The importance of clearly defining roles lies in providing optimal system access, allowing users with different tasks to perform their functions with maximum efficiency. Each role has specific responsibilities that contribute to the collection, analysis, and processing of data, ensuring safety and improving productivity in the mining industry. Below are the main user roles and their responsibilities.

GeoDATA Zones System Users and Their Functions.

1. Surveyor/Geologist:

– Data collection: Conducts surveying to detect changes in rock formations and collects geological data for analysis and assessment of quarry field conditions.

– Geological data analysis: Analyzes collected data to assess the condition and stability of rock masses, considering factors such as water saturation and geophysical characteristics.

– Data entry: Submits processed data to the system for further processing and analysis.

2. System Administrator:

– User management: Creates, edits, and deletes user accounts, providing or restricting access to the system.

– System monitoring and maintenance: Ensures the system's stability and security, implements software updates, and resolves technical issues.

– System configuration: Configures system parameters to ensure efficient data processing and meet security requirements.

3. Inspector:

– Safety monitoring: Receives reports and alerts on potential risks and hazardous conditions, analyzes this information to ensure workplace safety.

– Safety status assessment: Conducts safety inspections to ensure compliance with safety standards and develops measures to address identified issues.

– Documenting actions: Records data on incidents and safety violations that occur during monitoring.

4. Data Analyst:

– Data processing and analysis: Collects data necessary for analysis, applies statistical and analytical tools to identify trends and anomalies that could affect mining safety and efficiency.

– Report creation: Prepares reports based on data analysis, including conclusions and recommendations for management decisions.

– Data visualization: Uses tools to create visualizations that help understand the results and present them in a user-friendly format for decision-making.

In the GeoDATA Zones system, the structure of the database is a critically important component, ensuring effective information management and support for various functional capabilities. A well-designed structure allows the integration of geophysical, surveying, and other data necessary for comprehensive monitoring of mining objects. It includes entities such as geophysicists, zones, safety factors, and others, each with its own attributes that reflect specific characteristics such as identifiers, values, and timestamps. This structure ensures the interconnection of data, optimizes the speed of access and data processing, and maintains a high level of security and data integrity. It allows users to access critical information in real-time, necessary for decision-making in mining operations.

Database Structure:

1. Geofisic: This entity represents geophysicists responsible for measuring geophysical parameters in various zones.

– Geofisic ID: integer(10) (Primary Key) – Unique identifier for the geophysicist.

– Geofisic Full Name: varchar(255) – Full name of the geophysicist.

– Instrument Factory Number: integer(10) – Factory number of the instrument.

2. Impact of the mine: This entity refers to the presence of the influence of underground mine workings or voids within the zone.

– ID of mine measurement: integer(10) (Primary Key) – Identifier of the mine impact measurement.

– Geofisic/GeoFosic ID: integer(10) – Identifier of the geophysicist conducting the measurements.

– ZonesZoneID: integer(10) – Zone identifier where the measurements were taken.

– Measurements Time: time(7) – Time of measurement.

– Value of impact: real(10) – Impact value measured by a gravimeter or converted to a dimensionless quantity.

3. Fractal dimension: This entity includes data on fractal measurements in the zones of influence.

– Fractal ID: integer(10) (Primary Key) – Identifier of the fractal dimension measurement.

– ZonesZoneID: integer(10) – Zone identifier where the measurements were taken.

– Geofisic/GeoFosic ID: integer(10) – Identifier of the geophysicist conducting the measurements.

– Fractal dimension: real(10) – Fractal dimension measured in the zone.

– Measurements Time: time(7) – Time of measurement.

4. Factor of safety (FoS): This entity includes data on the safety factor in the zones of influence.

– Factor of safety ID: integer(10) (Primary Key) – Identifier of the safety factor measurement.

– ZonesZoneID: integer(10) – Zone identifier where the measurements were taken.

– Geofisic/GeoFosic ID: integer(10) – Identifier of the geophysicist conducting the measurements.

– Value: integer(10) – Value of the safety factor measured in the zone.

– Measurements Time: time(7) – Time of measurement.

5. Zones: This entity represents the geographical or conditional zones that are studied or monitored as part of the project.

– ZoneID: integer(10) (Primary Key) – Unique identifier of the zone.

– Zone name: varchar(255) – Name of the zone.

– X1Coordinate – Y4Coordinate: real(10) – Coordinates of the zone (4 points for positioning).

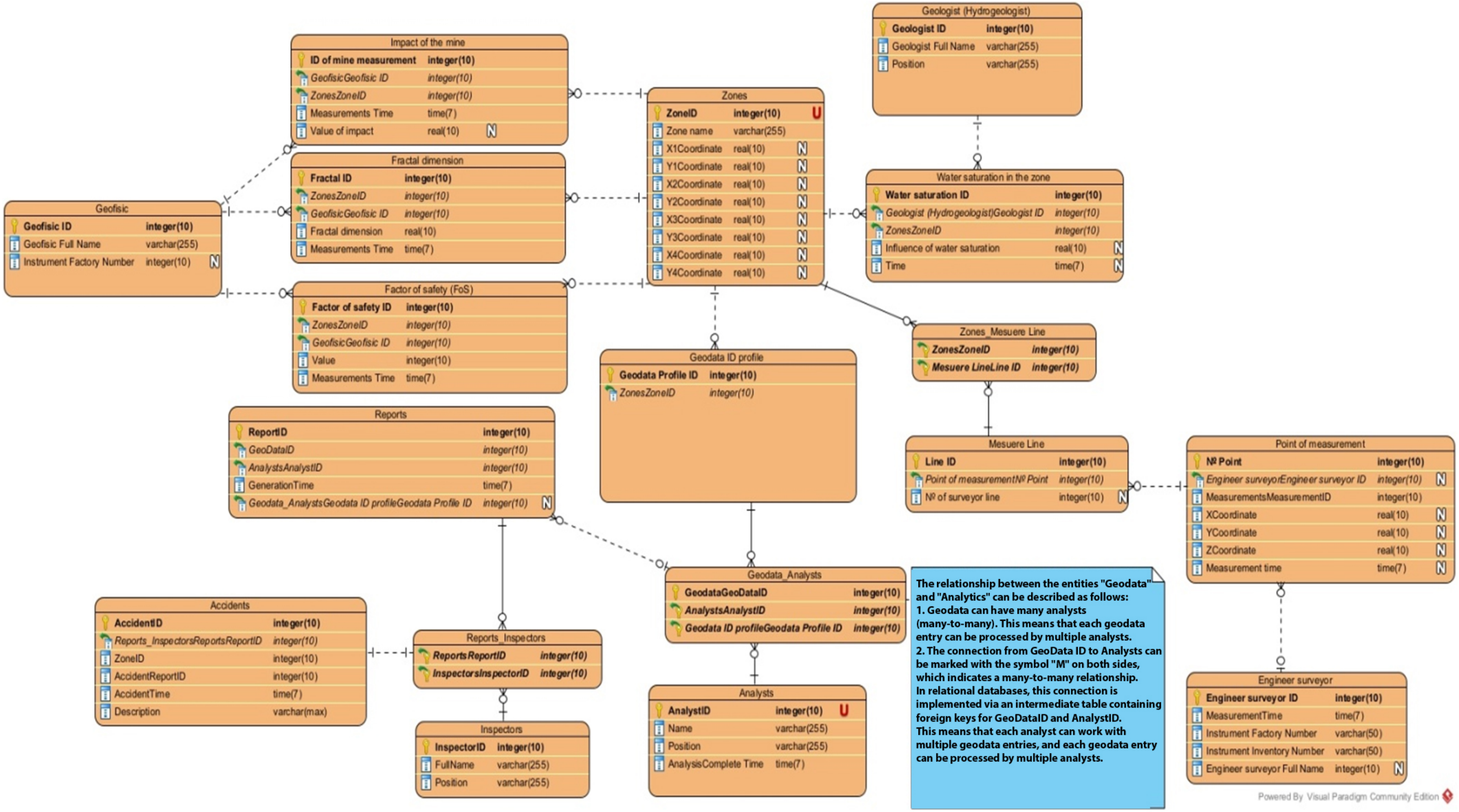

Figure 1 – Entity-relationship diagram

6. Geologist (Hydrogeologist): This entity represents geologists specializing in hydrogeology or geology.

- Geologist ID: integer(10) (Primary Key) – Unique identifier of the geologist.
- Geologist Full Name: varchar(255) – Full name of the geologist.
- Position: varchar(255) – Position (geologist, hydrogeologist).

7. Water saturation in the zone: This entity includes data on the water saturation level of the ground in the study zones.

- Water saturation ID: integer(10) (Primary Key) – Identifier of the water saturation measurement.
- Geologist ID: integer(10) – Identifier of the geologist conducting the measurements.
- ZonesZoneID: integer(10) – Zone identifier where the measurements were taken.
- Influence of water saturation: real(10) – Influence of water saturation on the zone.
- Time: time(7) – Time of measurement.

5. Conclutions

1. Improving mining safety: During development, the GeoDATA Zones system has the potential to significantly enhance mining safety by integrating geophysical and surveying data. The system is expected to enable timely identification of potential risks such as landslides and collapses, ensuring quick decision-making and the implementation of appropriate safety measures.

2. Innovative approach to data management: The development of GeoDATA Zones is based on an innovative approach to managing large volumes of data, which includes the use of machine learning algorithms and artificial intelligence. This approach is intended to ensure efficient data analysis, forecasting potential threats, and developing risk mitigation strategies, ultimately improving mining operations' efficiency.

3. Scalability and integration with other systems: The GeoDATA Zones database is designed to ensure future scalability and the ability to integrate with other systems used in the mining industry. This will allow for the storage and processing of growing data volumes without loss of performance, as well as integration with tools like Power BI for data visualization.

4. Ensuring data integrity and security: In the development of GeoDATA Zones, significant attention is given to ensuring data integrity and security. The implementation of authentication and authorization mechanisms will provide access control, and regular data backups are intended to protect against data loss in emergency situations, which is critical for information security.

5. Diversity of users and their roles: GeoDATA Zones supports a variety of users, including surveyors, geologists, inspectors, system administrators, and analysts. Each role will have its specific functions, ensuring a comprehensive approach to data collection, processing, and analysis, as well as supporting safety in the workplace.

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РОЗРОБКА ЕФЕКТИВНОЇ БАЗИ ДАНИХ ГЕОФІЗИЧНОГО ТА МАРКШЕЙДЕРСЬКОГО МОНІТОРИНГУ ДЛЯ СИСТЕМИ GEODATA ZONES

Романенко А.

Анотація. У статті розглядається розробка вдосконаленої бази даних, призначеної для інтеграції та аналізу геофізичних і маркшейдерських даних у системі моніторингу GeoDATA Zones, яка спеціально адаптована для використання на кар'єрах. Сучасні гірничі операції стикаються зі значними ризиками, такими як зсуви, обвали та інші геологічні небезпеки, що виникають через неефективне управління даними. Система GeoDATA Zones вирішує ці проблеми шляхом впровадження інноваційних методів обробки даних із використанням алгоритмів машинного навчання та штучного інтелекту. Основна мета статті — показати, як розробка структурованої бази даних може покращити швидкість, точність та надійність аналізу геофізичних і маркшейдерських даних, що, своєю чергою, підтримує більш ефективний процес прийняття рішень.

У статті детально розглядаються ключові фактори, що впливають на стійкість гірських масивів, такі як геологічні утворення, фізичні властивості порід, тріщинуватість і вплив поточних гірничих робіт. Крім того, аналізуються й інші фактори, зокрема насичення водою та сейсмічна активність, які можуть додатково дестабілізувати породи. Стаття підкреслює важливу роль добре спроектованої бази даних, яка забезпечує цілісність, безпеку та масштабованість даних, а також можливість інтеграції з іншими системами, що використовуються у гірничій промисловості. Проектування бази даних враховує як логічну, так і фізичну структури, причому основною системою управління базами даних обрано Microsoft SQL Server. Крім того, для покращення інтерпретації даних, аналізу та створення звітів використовуються інструменти візуалізації, такі як Power BI, що дають можливість приймати рішення в реальному часі.

Процес розробки бази даних включає впровадження надійних заходів безпеки, таких як багаторівнева автентифікація користувачів, шифрування даних і протоколи контролю доступу, які захищають систему від несанкціонованого доступу та забезпечують її стійкість. Результати досліджень показують, що система GeoDATA Zones може суттєво підвищити ефективність, безпеку та сталість гірничих робіт, що сприятиме довгостроковому успіху гірничих підприємств. Це рішення сприяє проактивному прийняттю рішень і зменшенню ризиків, що відповідає прагненню галузі до більш сталих і екологічно відповідальних гірничих практик.

Ключові слова: геофізичний стан, стійкість гірських масивів, управління базами даних, виявлення порожнин у гірських породах, машинне навчання, безпека гірничих робіт, інтеграція даних, сталі гірничі практики.