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DEVELOPMENT OF A WEB-BASED 3D VISUALIZATION TOOL THAT CAN BE USED IN GEOSCIENCE STUDIES

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Abstract: *3D modelling is the process of creating and representing three-dimensional geometric models of objects. These models enable real-world objects to be transferred to the digital environment. 3D modelling is used in many fields such as architecture, engineering, game development, animation, film production, product design, data visualization and virtual reality. Data visualization makes data more natural for the human mind to understand and thus facilitates the identification of trends, patterns, and outliers within data sets. Therefore, it has a critical importance in the management and interpretation of data. 3D visualization studies are a necessary 3D presentation tool for the project design processes as well as the sales and marketing phase. The aim of this study is to develop an interactive web application to model and visualize the discontinuity network of a natural stone quarry in 3D using WebGL technology. The study includes technical developments in web- based 3D modelling, data visualization, interactive user interface, and data integration. Additionally, topics such as how to use WebGl technology for quarry modelling, data management, simulation techniques and user experience optimization are also focused on.*
Keywords: *3D modelling, WebGl, Three.js, Natural stone, Representative Prism, Optimization*

1. Introduction

3D modeling is the process of creating and representing three-dimensional geometric models of objects. These models enable the digital representation of real-world objects. 3D modeling is widely used in various fields such as architecture, engineering, game development, animation, filmmaking, product design, and virtual reality.

In the realm of mining engineering, several scholarly papers have discussed various 3D visualization tools and methodologies. For example, the Google Earth application has been utilized for 3D geological modeling and the visualization of rock masses [1]. Virtual Reality (VR) technology has been applied in mining and civil engineering for immersive visualization experiences [2]. Shear-Warp Volume Rendering Technology has been employed for constructing underground 3D visualization models in mining engineering [3]. Surpac software has been used for constructing and visualizing three-dimensional models of engineering geological bodies [4].

In geoscience research, several web-based 3D visualization tools are available to facilitate the interpretation and communication of complex geological data. The HOOPS Communicator SDK is a robust web-based graphics engine designed for the mining and geoscience sectors, developed by Tech Soft 3D [5]. It features optimized streaming technology, enabling users to view extensive models within seconds. This tool is instrumental in transitioning applications to cloud-based platforms, thereby enhancing accessibility and collaboration among geoscientists. Geoscience ANALYST [6] is a free standalone application that allows users to import, visualize, annotate, save, and distribute a variety of 3D geoscience and mining data and models. It supports integrated, multi-disciplinary datasets, making it a valuable tool for geoscientists aiming to analyze and share complex geological information effectively. Leapfrog Geo, offered by Seequent [7], is an industry-

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leading 3D modeling software that enables rapid integration, communication, and interpretation of geological data. It is particularly beneficial in identifying trends within datasets, facilitating informed decision-making in geological modeling and resource estimation. GemPy [8] is an open-source, Python-based project dedicated to generating 3D structural geological models. Utilizing an implicit modeling approach, it allows for the creation of complex combinations of stratigraphical and structural features, including folds, faults, and unconformities. GemPy is specifically designed for probabilistic modeling to effectively address parameter and model uncertainties, making it a versatile tool in academic and research settings. V3Geo [9, 10] is a cloud-based repository designed for publishing virtual 3D models in geoscience. The system allows for the storage, search, and visualization of mesh models, promoting open science and facilitating the sharing of geological models and interpretations within the scientific community. NASA WorldWind [11] is an open- source virtual globe API that enables developers to create interactive visualizations of 3D globe, map, and geographical information. It is utilized by organizations worldwide to monitor weather patterns, visualize cities and terrain, track vehicle movement, analyze geospatial data, and educate the public about Earth. OpenWebGlobe [12] is a project and technology for processing and interactively visualizing vast volumes of geospatial data in a 3D virtual globe. It supports several data categories, including image data, elevation data, points of interest, vector data, and 3D objects, making it a comprehensive tool for geospatial visualization. Avizo [13] is a software application for scientific and industrial data visualization and analysis. It offers features such as 2D and 3D image stack and volume data import, geometric model handling, numerical simulation data integration, and molecular data visualization. Avizo is used in various fields, including materials science, engineering, and geosciences, for tasks like image processing, 3D model reconstruction, and quantitative analysis. Verge3D [14] is a real-time renderer and toolkit used for creating interactive 3D experiences running on websites. It enables users to convert content from 3D modeling tools to be viewed in a web browser, facilitating the development of interactive scenarios and applications in various domains, including geosciences. GPlates [15] is an interactive visualization software that allows geoscientists to explore plate tectonics. It supports the interactive manipulation of plate-tectonic reconstructions and the visualization of geodynamic models, making it a valuable tool for understanding geological processes over geological timescales.

1.1. 3D Visualization in Mining Engineering: Tools, Applications, and Advances

In mining engineering, the integration of 3D visualization tools has significantly enhanced the analysis and interpretation of geological data. These tools facilitate the creation of detailed three-dimensional models of subsurface structures, enabling engineers to visualize complex geological formations and assess mining operations more effectively. For instance, the application of 3D modeling techniques has been demonstrated in large-scale mining projects, where fractal interpolation algorithms are employed to generate accurate geological models under real-world conditions [16].

Furthermore, the development of underground 3D visualization technologies has proven instrumental in constructing models of mining roadways and areas, thereby improving the planning and safety of mining operations [3]. Advancements in visual modeling technologies, particularly those based on deep learning, have further refined the accuracy and efficiency of 3D models in mining engineering [17]. The progression of 3D visualization technologies in mining has been extensively documented, highlighting their evolution and the latest research developments in the field [18]. Additionally, the integration of 3D geological and numerical modeling methods, involving multi-software coupling, has enhanced the precision of subsurface models, thereby supporting more informed decision-making in mining operations [19].

The application of 3D visualization extends beyond modeling to include the simulation of geomechanical states within rock masses, aiding in the prediction and analysis of seismic events in mining environments [20]. Moreover, the use of Python-based applications for constructing computerized 3D visualizations of geological structures has further advanced the field, offering customizable and efficient solutions for geological modeling [21]. Collectively, these advancements underscore the critical role of 3D visualization tools in modern mining engineering, enhancing the accuracy, safety, and efficiency of mining operations through improved geological modeling and analysis.

The integration of 3D modeling and data visualization has become a cornerstone in various scientific and engineering disciplines, including mining engineering. This synergy enhances the comprehension and analysis of complex geological data, thereby improving decision-making processes. In geoscience, the development of cloud-based repositories for virtual 3D models has significantly advanced the storage, search, and visualization of mesh models. Platforms like V3Geo facilitate the management of 3D models, enabling researchers to access and interact with geological data more effectively [22]. Additionally, GPlates Portal offers a cloud-based interactive 3D visualization of global geophysical and geological data. By utilizing

WebGL technology, it allows for the fast and interactive visualization of extensive datasets, draped over digital terrain models, thereby enhancing the understanding of geological processes [23]. WebGL technology has been instrumental in advancing 3D visualization methods. A study on seismic tomography CT results demonstrates how WebGL enables high-efficiency visualization independent of specific software, utilizing wave velocity reference points to create grids and applying vertex and surface coloring to models [24]. Furthermore, WebGL's application in data visualization has been explored to create interactive globe presentations, allowing developers to present data tied to geographical locations in an engaging manner.

In mining engineering, the application of 3D visualization tools has been explored to enhance the modeling and visualization of geological and mining data. Extreme GIS applications have been developed for 3D visualization aimed at geological and mining modeling, demonstrating the ability to interactively visualize various geological data [25]. Additionally, the development of three-dimensional documentation and virtual web navigation systems has been proposed for the exploration of complex cultural heritage sites, highlighting the potential of 3D visualization in various fields [26]. Several frameworks have been developed to facilitate 3D visualization in web applications. Babylon.js, for instance, is a real-time 3D rendering engine for JavaScript that enables the creation of interactive 3D worlds in the browser. Similarly, Verge3D is a real-time renderer and toolkit used for creating interactive 3D experiences running on websites, supporting the conversion of content from 3D modeling tools to web-viewable formats.

These advancements underscore the critical role of 3D visualization tools in modern mining engineering, enhancing the accuracy, safety, and efficiency of mining operations through improved geological modeling and analysis.

1.2. 3D Modeling and Data Representation

3D models typically consist of combinations of geometric elements such as points, edges, surfaces, and volumes. These models can be created using CAD (Computer-Aided Design) software, modeling software, or 3D scanning technology.

Data representation concerns how 3D models are represented in digital formats. Essentially, it refers to data containing the geometric and topological information of 3D objects. The data of a 3D model may include information such as the coordinates of points, connections of edges, normal vectors of surfaces, and color or material information.

3D data is often represented in the form of triangular meshes (triangulation) or point clouds. Triangular meshes are a common method that connects triangular surfaces. Point clouds, on the other hand, are data structures that provide the coordinates of three-dimensional points.

3D models and data representations can be stored and shared through various file formats. For example, the STL (Stereolithography) file format is a standard used by 3D printers. Other commonly used file formats include OBJ, FBX, Collada (DAE), and glTF.

In conclusion, 3D modeling and data representation play a vital role in representing physical objects in the digital world, enabling applications such as design, analysis, visualization, and production.

1.3. WebGL and Three.js for Natural Stone Quarry Modeling and Visualization

This paper focuses on the development of a Natural Stone Quarry modeling and visualization application using WebGL and Three.js. The objective of this study is to create an interactive web application for modeling and visualizing a natural stone quarry in 3D using WebGL and Three.js technologies. This application will serve as a valuable tool for professionals and researchers in the natural stone quarry industry.

2. Methodology

The specific objectives of this paper can be outlined as follows:

1. Creation of 3D Models for Different Areas and Processes in the Natural Stone Quarry: The goal is to develop 3D models for various areas, mineral deposits, equipment, and processes within the natural stone quarry. Initially, these models will have a low level of detail. The feasibility of these models representing the natural stone quarries in a realistic and precise manner will be evaluated.
2. Facilitating User Interaction: The application will feature interactive capabilities that allow users to explore different areas and processes within the natural stone quarry. Users will be able to rotate, zoom in and out, view different cross-sections, and access detailed information.
3. Data Visualization and Analysis: The application will provide tools for visualizing and analyzing data from the natural stone quarry. Information such as the geographic distribution of data, volumes, and statistics related to operations will be presented through graphs and visual representations.

4. Training and Simulation: The application has the potential to offer simulations that can be used for training purposes in the natural stone quarry industry. Students and new employees can virtually experience processes within the quarry, understand workflows, and learn about potential issues.
5. Data Integration: The application will partially integrate data from existing databases or maps, enabling the use of real-time data updates, geographic references, and other relevant information.

The paper discusses the development of web-based 3D modeling, data visualization, interactive user interfaces, and data integration. In-depth research on WebGL and Three.js technologies has been conducted to explore how these technologies can be applied in natural stone quarry modeling. Additionally, the focus is placed on data management, simulation techniques, and user experience optimization.

The importance of this paper and its product lies in offering a solution for companies that wish to operate more efficiently, safely, and sustainably, as the use of digital technologies in the natural stone quarry industry continues to grow. This application will enable quarry operators and researchers to improve planning, resource management, training, and analysis capabilities. Furthermore, it will contribute to innovation and digital transformation efforts in the industry, helping companies gain a competitive advantage.

In this project, a computer-aided application is being developed based on 3D discontinuity systems in natural stone deposits, utilizing analytical, mathematical, machine learning, and big data solutions.

In the developed prototype software, a 3D discontinuity network is formed from the mirror (cutting surface used for production) image, allowing the definition of natural polyhedra.

The 3D mapping of the rock mass structure (Discontinuity Network Model) is an essential task in many applications of mining engineering. The software, previously developed for academic purposes and now being commercialized, uses "linear isometric projection of the rock mass (LIP-RM)" for visualizations [27]. In this simulation software, 2D isometric representations have been preferred. The model produced in the back-end is prepared in 3D according to the principles of Distinct Element Analysis (DEM) for the rock mass network model. LIP-RM can evaluate definition data such as the dip/dip direction and distance between discontinuities, but it is based solely on measurements from the tape meter measurement line.

In the current study, field data is diversified. In addition to the tape measure, survey techniques such as Ground Penetrating Radar (GPR), Electrical Resistivity, Point Clouds, and Drilling will also provide input for the portal. In part of this study, discontinuity surfaces are defined using point clouds obtained from photo analysis data. Thus, disadvantages such as the accessibility in 1D scan-line measurements are eliminated, and more realistic and faster data is obtained.All data is stored in an Information System Table, ensuring a more realistic definition of discontinuities on the excavation surface. This allows for the adaptation of new approaches to previously developed codes, facilitating the transition to the efficiency evaluation phase.

The basic analytical and experimental solution methods applied to achieve the paper's objectives are as follows:
1. Data Collection: At the beginning of a new project in the portal, physical characteristics, geographic data, equipment, processes, and other relevant information of the natural stone quarry must be collected. This data can be obtained from field studies, maps, source documentation, or existing databases. During the data collection phase, careful planning is required to identify necessary data, determine sources, and ensure data compatibility.
2. 3D Modeling: After data collection, 3D models of natural stone quarry are created using WebGL and Three.js. A database or data structure is established to store the data that will be used. The 3D modeling process requires accurate representation of different areas, mineral deposits, equipment, and processes within the quarry. 3D modeling software and algorithms can also be utilized at this stage.
3. Data Integration and Analysis: In addition to the created 3D models, the integration of real-time data from the natural stone quarry can also be partially achieved. This can be done using data integration tools and APIs. For data analysis, appropriate analysis methods and algorithms will be used to visualize the quarry's data, perform segmentation, analyze its geographic distribution, and conduct other statistical analyses in future work.
4. User Interface and Interaction: The application will feature a user interface design that allows users to interactively explore 3D models. This interface will allow users to rotate, zoom in, create cross- sections, and access detailed information. As the project progresses, the user interface should be developed based on user feedback, and the user experience should be optimized.
5. Performance and Optimization: The application's performance is critical, including fast loading times, smooth animations, and low resource consumption. Therefore, the application's performance should be continuously monitored and optimized. Various performance tests have been conducted, and necessary improvements have been partially implemented.

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These methods encompass the analytical and experimental solution approaches that will be used to achieve the specific project objectives.

3. Research results and outputs

The processes of producing the contents of the modules have been successfully completed by advancing with software developed in Python. During the process, different versions of the software modules were obtained. In the first version of the project's web portal, "aicostqo" the updated versions of the software modules were made live. Subsequently, interface designs were optimized, efficiency improvements were made in polyhedral calculation processes, and performance tests for the portal were conducted. The portal's main page was made operational. The interfaces for the modules were made live, and additional interfaces for other required modules were also developed. Below, the activities related to interface designs are discussed under several subheadings.

Web-Based 3D Visualization: The application, initially developed as a desktop module, has been successfully transformed into a web application. The relevant 3D visualization modules are fully prepared for cloud infrastructure and continue to use OBJ files as the underlying system. The application is not merely an OBJ viewer, but a fully functional web tool embedded directly into the webpage with connections to interfaces. All the data for the scenes to be visualized in 3D is fed directly from the cloud-based database. User interactions are progressively being integrated into the portal. Two different portals have been made live, using two different technologies and interface design contents. (The portals can be accessed at https://www.aicostsqo.io and https://www.aicostsqo.com) (Figure 1 and 2).

Fig.1. Interface of the AICOSTSQO project portal

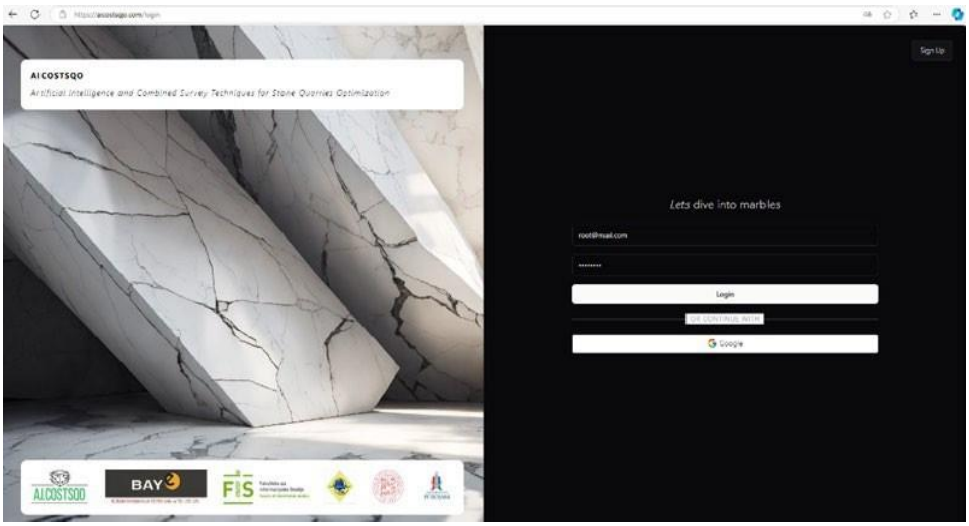

Fig.2. Interface of the AICOSTSQO project login page

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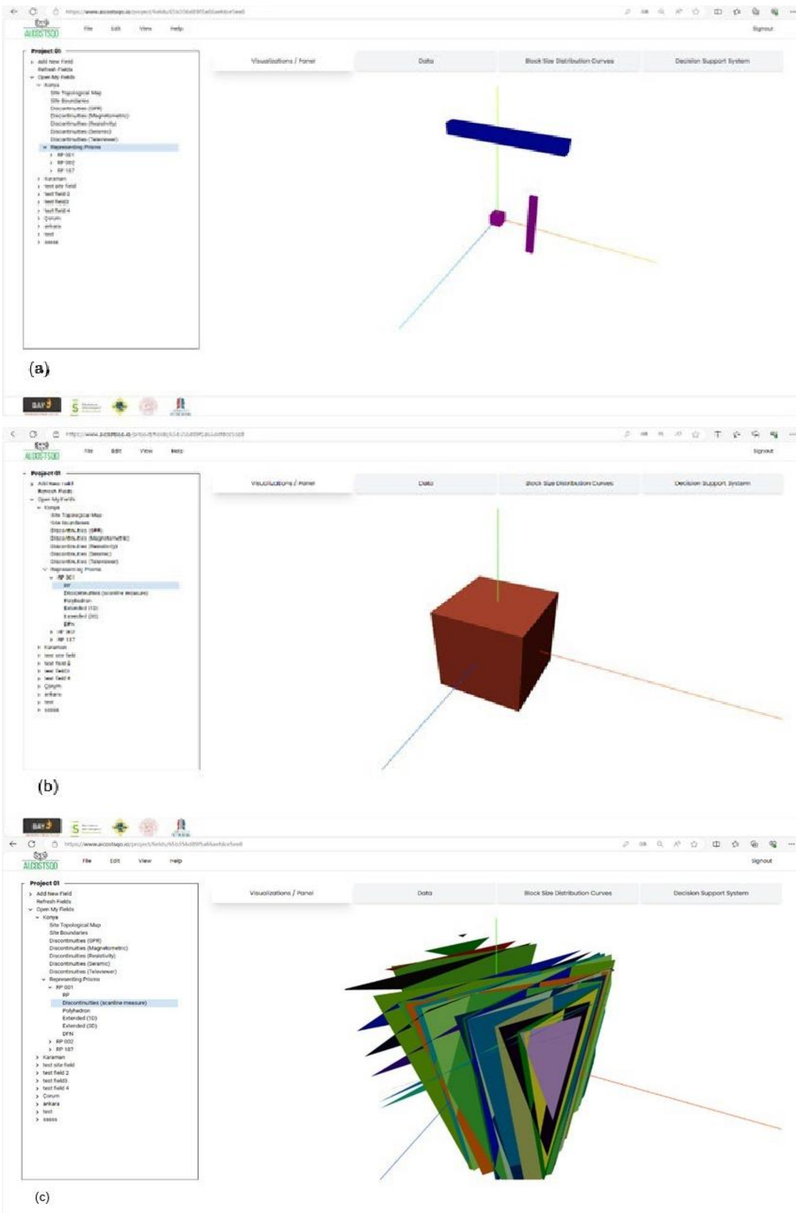
For the data required for 3D visualization, the table and attribute / field definitions have been clarified in the updated database content. The development phases of the web-based 3D visualization tool progressed in the following order:

1. Project Planning and Design Analysis,
2. Data Collection and Preparation,
3. 3D Modeling and Data Integration,
4. User Interface Development,
5. Simulation and Training Modules,
6. Performance and Optimization,
7. Testing, Feedback, and Finalization.

Ultimately, the infrastructure we reached has demonstrated the requirements and technical level of 3D visualization. In the live system, the capabilities of the previous MATLAB application have been activated with a different infrastructure using web technologies, and a structure has been reached where discontinuity planes can be directly produced within the Representative Prism (RP). Polygon calculations and outputs can also be obtained. The data can be retrieved from different database technologies defined in the cloud. For example, the collective RPs of a system with three different RPs, a 3D representation for one RP selected from these three, images of discontinuity planes obtained from fieldwork within the RP, polygons obtained by passing these discontinuity planes through the RP, and even results of the DFN application for the same RP are shown in some sample interface screenshots obtained from the live system, as presented in Figure 3. a, b, c, d, e and f.



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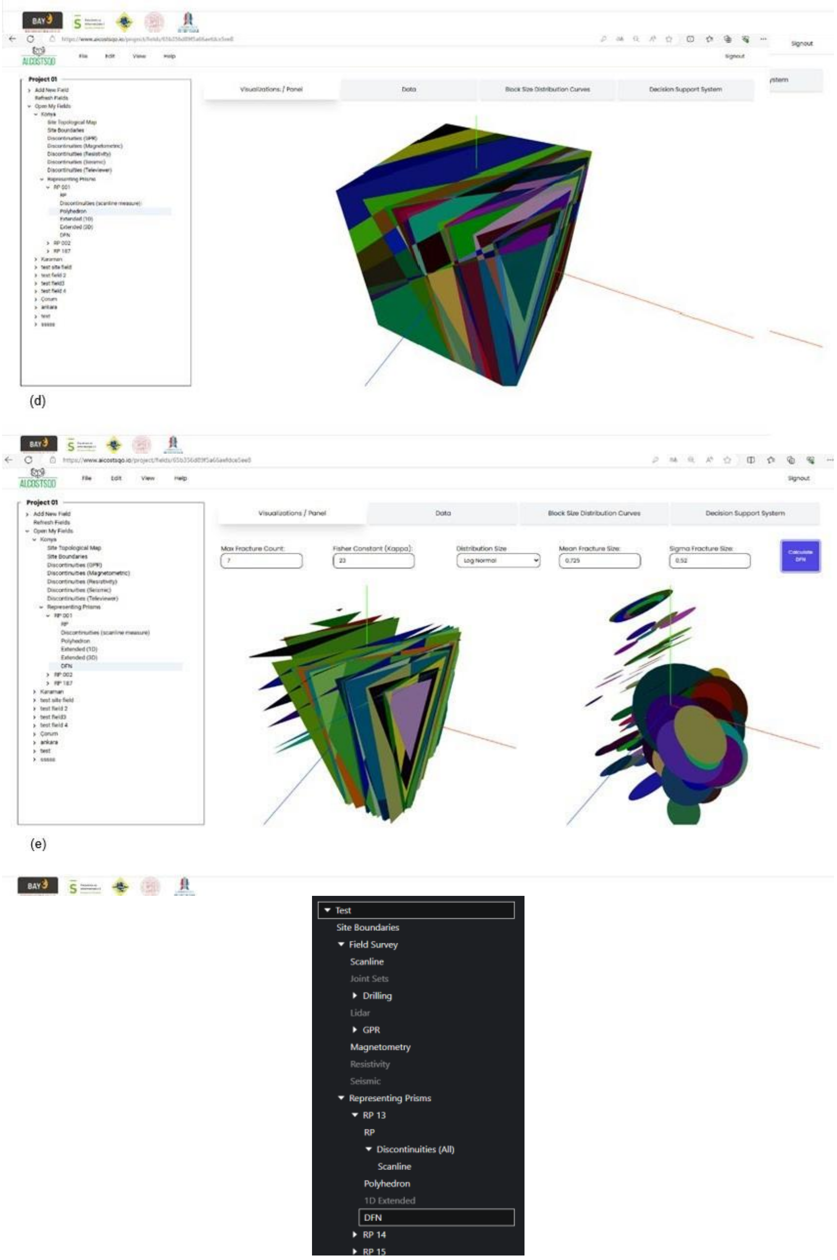

Fig.3. Example screenshots of the results of a DFN application for the same RP: a) the collective RPs of a system with three different RPs; b) a 3D representation for one RP selected from these three; c) images of discontinuity planes obtained from fieldwork within the RP; d) polygons obtained by passing these discontinuity planes through the RP; e) results of the DFN application for the same RP; f) Menu options

The figure shows some sample interface screenshots displaying the results of the DFN application. While developing the tool, an extended 1D Scan-line Visualization study was also conducted. This extension was initially made with the previous LIP-RM software [27]. This paper represents the authors' previous academic work, which is believed to have relevance in the industry, and thus it was deemed appropriate to include it in the web portal. The first version of the idea and product, which was originally developed in Microsoft Visual Basic Programming Language and contributed to academia, has been successfully transformed from a desktop software into a web application. In the module, the technical details can be found in the Turanboy and Ülker (2008) [27]. paper, where all requirements have been addressed, and a complete web module has been achieved. Based on all deterministic or stochastic discontinuity data measured in projects, a 1D extension work can be done to support the assumptions of the invisible side of the RP. The scenes/reflectors to be extended on the left and right of the visible mirror part, the planes corresponding to the RP in the field of view after extension, and the final version of the RP after extension can be autonomously reached. Screen images from the live portal for RP are shown in Figure 4. The results of the 1D and 3D extensions, including example applications, are also provided as screenshots obtained from the live web portal.

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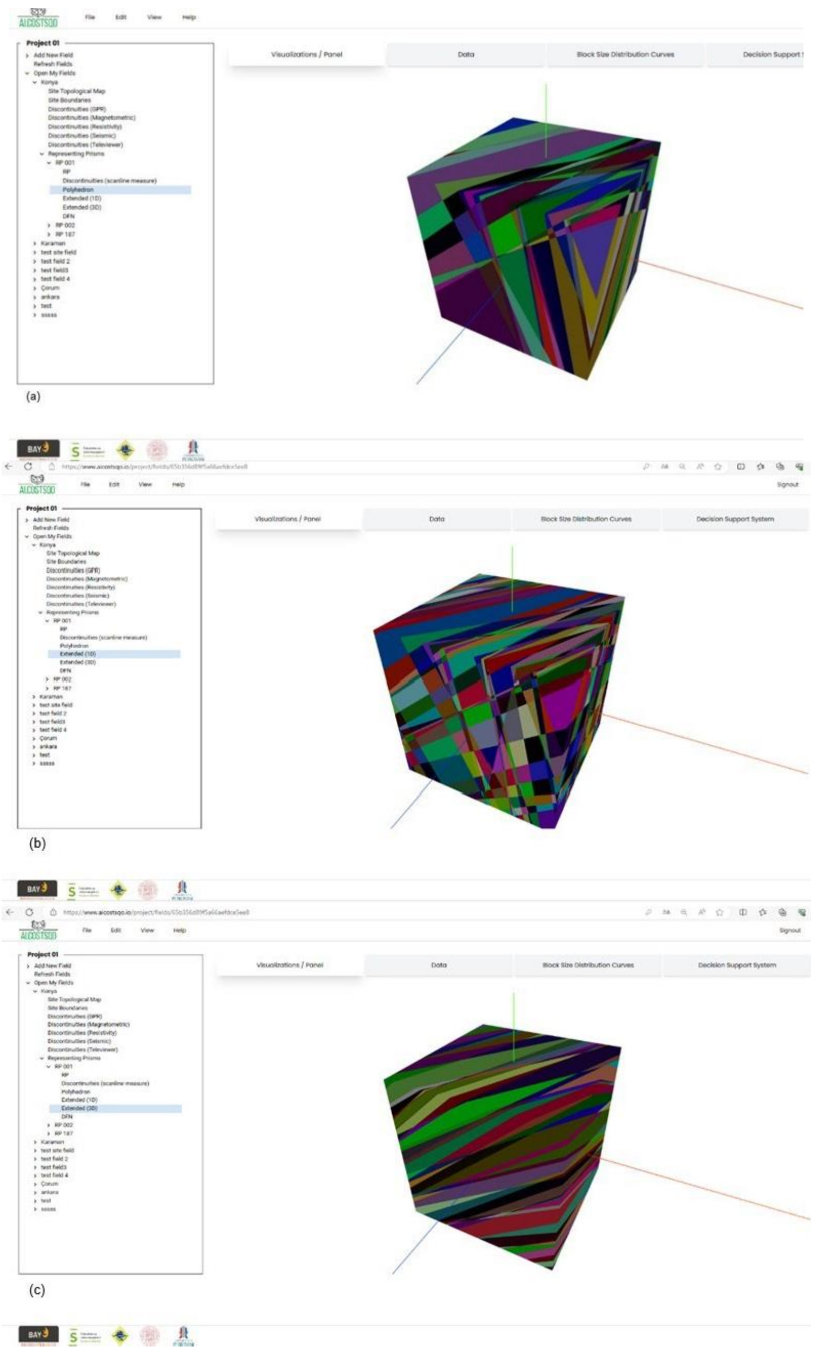

Fig.4. Result of a application: a) the original; b) 1D and; c)3D extensions of RP(s) in live web portal

4. Discussion

In the field of geosciences, 3D visualization is used to better understand, analyze, and visualize geographic data and geological structures. Below are the objectives of 3D visualization in the geosciences field:

1. Visualization of Landforms and Topography: 3D models allow for a more realistic visualization of landforms such as mountains, valleys, rivers, and plateaus. This enables better understanding of geographic data and makes it easier to see the characteristics of the terrain.
2. Analysis of Geological Structures: Understanding and analyzing geological structures is crucial in geosciences. 3D visualization allows for a more detailed examination of geological structures such as fault lines, sedimentary layers, and volcanic formations. This helps to better understand the relationships between structures, layer arrangements, and deformations.
3. Hydrological Analyses: 3D visualization is essential in hydrological analyses such as water resource management, watershed analysis, and flood prediction. Visualization of water flow, hydrological models, and riverbeds helps in the effective management of water resources.

4. Visualization and Simulation of Natural Disasters: Simulating and visualizing natural disasters like earthquakes, volcanic eruptions, and landslides require the use of 3D models. These models are used to understand the effects of disasters, conduct risk analyses, and develop preventive measures.
5. Research and Education: 3D visualization contributes to research and educational activities in geosciences. Students and researchers can use interactive 3D models to better understand geographic data, geological structures, and other geoscience elements.
In conclusion, 3D visualization in geosciences is an important tool used for better understanding, analyzing, and visualizing geographic data and geological structures. This technology supports research in geoscience and provides valuable information for applications such as urban planning, disaster management, and resource management.

Innovative Aspects and Technological Value:
1. Use of WebGL and Three.js Technologies: This study utilizes powerful web-based technologies such as WebGL and Three.js. These technologies allow for the creation of real-time 3D graphics through browsers. When used for natural stone quarry modeling, they offer users an interactive and realistic experience. This approach, which is more interactive and informative than traditional 2D maps or static images, makes the study innovative.
2. Real-Time Data Integration: Another innovative aspect of the study is the integration of real-time data. The live integration of data from the natural stone quarry (such as mining beds, equipment, and operations) into the application provides users with up-to-date information. This optimizes data management and updating processes, enabling more efficient decision-making.
3. Interactive User Experience: The study’s focus on interactive user experience is an innovative approach. Users can explore the natural stone quarry in 3D, rotate models, create cross-sections, and access detailed information. This allows users to better understand the quarry processes and make more informed decisions.
4. Data Analysis and Visualization: The data analysis and visualization features provided by the portal make it easier to explore data from the natural stone quarry in an innovative way. Users can better understand data through visual representations of geographic distributions, volumes, statistics, and other analytical data. This helps businesses make better decisions and develop data-driven strategies.
5. Training and Simulation Capabilities: The paper and portal offer innovative features that can be used for training and simulation purposes in the natural stone quarry industry. Students and new employees can experience working in a virtual natural stone quarry, learn workflows, and solve potential problems through simulations. This improves training processes and provides more effective learning.

5. Conclusions

The integration of 3D visualization technology in Geosciences has proven to be a transformative tool for enhancing the understanding and analysis of complex geological data. The development of an interactive, web-based 3D visualization tool for modeling and visualizing the discontinuity network of a natural stone quarry represents a significant step forward in applying modern technologies to geological studies. By utilizing WebGL and Three.js, this tool allows for the creation of scalable, interactive 3D models that can be accessed through any web browser, making it highly accessible and user-friendly.

The application of 3D visualization in the mining, energy, construction, and environmental sectors offers numerous benefits, including improved decision-making, enhanced data analysis, and better resource management. It also plays a critical role in disaster management, environmental impact assessments, and educational purposes, offering a more immersive and interactive learning experience.

As the technology continues to evolve, the tool's capabilities can be expanded to support more complex models, integrate additional data sources, and improve compatibility with other geological software. These advancements will further enhance their usefulness in real-world applications, providing a valuable resource for engineers, geologists, and professionals in the Earth sciences.

Ultimately, 3D visualization technology holds great promise for revolutionizing how geological data is analyzed, understood, and utilized. Its potential to improve efficiency, reduce risks, and support better decision-making across various industries ensures its continued relevance and growth in the future.

This paper explores the applications of 3D visualization technology in Earth sciences, particularly in sectors such as mining, energy, construction, and environmental analysis. 3D visualization is a powerful tool that enhances the understanding, analysis, and visualization of geographic data. Technology plays a significant role in natural resource exploration and management, disaster management, environmental impact analysis, education, and simulation.

In this study, an interactive web-based 3D visualization tool was developed for modeling and visualizing the discontinuity network of a stone quarry using WebGL technology. The tool provides an intuitive and effective platform for representing geological structures in a digital environment, allowing users to interact with the model and explore various data layers in real-time. By integrating 3D modeling, data visualization, and user-friendly interface design, the application improves the understanding of complex geological data, facilitating better decision-making in mining operations and structural geology studies.

The use of WebGL technology has proven highly effective for creating detailed, scalable, and interactive 3D models that can be accessed through any web browser, making the tool highly accessible. Furthermore, the integration of simulation techniques and data management features optimizes the user experience, ensuring that the tool is both functional and practical for professionals in the field.

Overall, the development of this web-based 3D visualization tool represents a significant advancement in the application of modern technologies to geological studies. It opens new possibilities for the visualization and analysis of geological data, offering a valuable resource for engineers, geologists, and other stakeholders involved in quarrying and mining activities. Future improvements could focus on expanding the tool's capabilities to support more complex models and enhancing its compatibility with other geological software for a more comprehensive analysis.

Industrial Outputs and Widespread Effects of 3D Visualization in Earth Sciences

1. Mining and Energy Sector: 3D visualization allows for more efficient exploration and management of underground resources. It helps to better understand the reserves and their distribution, increases efficiency in exploration and extraction processes, and reduces risks.
2. Construction and Infrastructure Projects: 3D visualization enhances the design process in large- scale infrastructure projects. By providing a visual representation to project stakeholders, it facilitates communication and helps identify potential issues before project completion.
3. Environmental Impact Analysis: 3D models are critical tools for evaluating environmental impacts and supporting the sustainable management of natural resources. They provide important information for monitoring land use changes, preserving habitats, and tracking ecosystems.
4. Disaster Management: 3D visualization plays an essential role in simulating and visualizing the impacts of natural disasters such as earthquakes, volcanic eruptions, and floods. It provides valuable information for disaster preparedness, risk analysis, and emergency planning. Additionally, 3D models can be used in post-disaster recovery processes for damage assessment and reconstruction efforts.
5. Tourism and Education: 3D visualization is used in the tourism industry to allow users to explore geographic regions, natural landscapes, and historical sites interactively. In Earth sciences education, it helps students understand geological processes, volcanic formations, mountain building, and other topics.

This application incorporates web-based technologies such as WebGL and Three.js, which enable the creation of real-time 3D graphics. These technologies allow users to experience interactive 3D visualizations and integrate real-time data, enhancing decision-making processes and providing a more detailed understanding of natural stone quarry operations. Additionally, the educational and simulation capabilities of the project improve the learning experience and contribute to more effective training.

In conclusion, 3D visualization in Earth Sciences and related sectors offers significant benefits in terms of efficiency, natural resource management, risk reduction, and education. This technology has proven to be an innovative tool and will likely continue to evolve and expand in its applications across various industries in the future.

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