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Visualization Design for Predictive Models of Fractured Well Production

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Abstract: This paper explores the visualization design for predictive models of fractured well production to enhance the intuitiveness and comprehensibility of the prediction results. Initially, the theoretical foundation of predictive models for fractured well production is established, encompassing geomechanics, fluid mechanics, and statistics. Subsequently, the methodology of visualization design is elaborated, which includes three main steps: data preprocessing, model construction, and result presentation. During data preprocessing, standardization and normalization techniques are employed to ensure data consistency and accuracy. In the model construction phase, multiple linear regression and neural network models are introduced and compared to determine the optimal model. For result presentation, various charts and dynamic interactive interfaces, such as heat maps, trend charts, and 3D models, are designed to enhance user visual experience and decision support capabilities. Finally, the paper summarizes the positive role of visualization design in improving the efficiency and accuracy of predictive model applications and proposes future research directions, including model optimization, innovation in visualization techniques, and deepening interdisciplinary research. This research provides theoretical support and practical guidance for the visualization design of predictive models for fractured well production, contributing to technological advancement and application expansion in the related field.

Keywords: Fractured Well; Predictive Model; Visualization Design; Multiple Linear Regression; Neural Network Model

1. Introduction

1.1 Research Background and Significance

Oil well fracturing technology, as a crucial method to enhance oil and gas extraction efficiency, has been widely applied globally. With the continuous development of oil and gas resources, how to effectively predict the production after oil well fracturing has become a critical issue. Traditional prediction methods often rely on experience and simple mathematical models, which struggle to accurately reflect complex geological and engineering conditions. In recent years, with the advancement of computer technology and data science, machine learning and big data analysis-based models for predicting oil well fracturing production have gradually become a research hotspot. However, the complexity of these models and the vast amount of data make the interpretation and application of results challenging. Therefore, how to visually present the results of complex prediction models through visualization technology has become an urgent problem to be solved.

1.2 Review of Domestic and International Research Status

In China, the research on oil well fracturing production prediction models started relatively early, undergoing a transition from traditional methods to modern technologies. Shang Fuhua (1998)[1] proposed a prediction model for oil well fracturing effects based on geostatistics, laying the foundation for early research. Subsequently, Liu Duanqi et al. (2004)[2] introduced a new method for predicting the potential of oil well fracturing, which improved prediction accuracy by comprehensively considering geological conditions and engineering parameters. Recently, with the rise of machine learning technology, Jiang Wenchao (2023)[3] used machine learning and model fusion techniques to predict the fracturing effects in the SN block of Daqing Oilfield, significantly enhancing prediction accuracy. Additionally, Hou Zhidong (2018)[4] verified the practicality and effectiveness of the model by predicting the production of individual wells after fracturing in the Putaohua Oilfield.

Abroad, significant progress has also been made in the research of oil well fracturing production prediction models. For example, Meng Hongxia et al. (2005)[6] proposed a hydraulic fracturing oil well productivity calculation model, providing important references for international peers. Yang Zhenzhou et al. (2003)[7] applied the grey topology method in fracturing well production prediction, showcasing the innovative capabilities in this field abroad.

Currently, the government places high importance on energy security and environmental protection, emphasizing the importance of green development and technological innovation in the Two Sessions spirit. Under this backdrop, the research on oil well fracturing production prediction models not only needs to improve prediction accuracy but also should focus on environmental impact assessment and sustainable development. For instance, Liu Jing et al. (2012)[5] explored new ways to reduce environmental pollution through a combustion-induced fracturing oil well productivity calculation model. In summary, significant progress has been made in the research of oil well fracturing production prediction models both domestically and internationally, but challenges still remain. In line with the Two Sessions spirit and current social hotspots, future research should place greater emphasis on technological innovation, environmental friendliness, and sustainable development to achieve effective exploitation and utilization of oil and gas resources.

1.3 Research Objectives

This paper aims to explore the visualization design of oil well fracturing production prediction models to enhance the intuitiveness and comprehensibility of prediction results.

2. Theoretical Basis of Oil Well Fracturing Production Prediction Models

2.1 Geological Mechanics Principles

Geological mechanics is the science of studying the laws of crustal stress and deformation, which is of great significance for oil well fracturing production prediction. The principles of geological mechanics mainly include the crustal stress field, rock mechanical properties, and fracture propagation mechanisms. The crustal stress field refers to the stress distribution within the earth's crust, which directly affects the formation and extension of fractures during fracturing. Rock mechanical properties include parameters such as the elastic modulus, Poisson's ratio, and tensile strength of rocks, which determine the deformation and fracture behavior of rocks during fracturing. Fracture propagation mechanisms refer to the generation, extension, and closure of fractures within rocks under external forces.

During oil well fracturing, high-pressure liquid injection causes fractures in the reservoir rocks, thereby improving the permeability and production of oil and gas. The principles of geological mechanics provide a theoretical basis for predicting the formation and extension of fractures. For example, by establishing a crustal stress field model, the direction and length of fractures can be predicted; by measuring rock mechanical properties, the width and flow capacity of fractures can be assessed. This information is of great reference value for the construction of oil well fracturing production prediction models.

2.2 Fluid Mechanics Principles

Fluid mechanics is the science of studying the laws of fluid motion, which also plays an important role in oil well fracturing production prediction. The principles of fluid mechanics mainly include fluid flow characteristics, seepage laws, and multiphase flow. Fluid flow characteristics include parameters such as fluid viscosity, density, and compressibility, which determine the flow behavior of fluids in the reservoir. Seepage laws refer to the flow laws of fluids in porous media, which are influenced by factors such as reservoir porosity, permeability, and pressure gradient. Multiphase flow refers to the co-flow behavior of oil, gas, water, and other fluids in the reservoir.

During oil well fracturing, high-pressure liquid injection improves the mobility of oil and gas in the reservoir, thereby increasing production. The principles of fluid mechanics provide theoretical support for predicting the flow behavior of fluids in the reservoir. For example, by establishing a fluid flow model, the diffusion range and speed of injected fluids can be predicted; by measuring the permeability of the reservoir, the production and recovery rate of oil and gas can be assessed. This information is of great reference value for the construction of oil well fracturing production prediction models.

2.3 Statistical Principles

Statistics is the discipline of data collection, analysis, and interpretation, which plays a key role in oil well fracturing production prediction. Statistical principles mainly include descriptive statistics, inferential statistics, and regression analysis. Descriptive statistics refer to the description and summarization of the basic characteristics of data, such as mean, variance, frequency distribution, etc. Inferential statistics refer to inferring overall characteristics from sample data, such as confidence intervals, hypothesis testing, etc. Regression analysis refers to establishing mathematical models to describe the relationship between variables, such as linear regression, nonlinear regression, etc.

During the process of oil well fracturing production prediction, by collecting and analyzing a large amount of geological and engineering data, prediction models can be established to improve prediction accuracy. Statistical principles provide methodological support for data processing and analysis. For example, through descriptive statistics, the basic characteristics and distribution of data can be understood; through inferential statistics, the reliability and accuracy of prediction models can be evaluated; through regression analysis, the relationship model between variables can be established to predict the production of oil wells. This information is of great reference value for the construction of oil well fracturing production prediction models.

3. Methodology of Visualization Design

3.1 Data Preprocessing Techniques

Data preprocessing is the foundational step of visualization design, aimed at improving data quality and consistency. Data preprocessing techniques mainly include data cleaning, data transformation, and data normalization. Data cleaning refers to the screening and correction of raw data, removing noise and outliers. Data transformation refers to the format conversion and encoding processing of data for subsequent analysis and processing. Data normalization refers to the standardization processing of data to give it the same dimension and range.

During the process of oil well fracturing production prediction, data preprocessing techniques can improve the quality and consistency of data, thereby enhancing the accuracy of prediction models. For example, through data cleaning, noise and outliers in the data can be removed to ensure data accuracy; through data transformation, data in different formats and encodings can be uniformly processed for subsequent analysis and processing; through data normalization, differences in data dimensions and ranges can be eliminated to improve the stability and reliability of models.

3.2 Model Construction Methods

Model construction is the core step of visualization design, aimed at establishing prediction models to improve prediction accuracy and reliability. Model construction methods mainly include multiple linear regression, neural networks, and support vector machines. Multiple linear regression refers to establishing a linear model to describe the relationship between multiple variables and predict oil well production. Neural networks refer to simulating the structure and function of biological neural networks to establish a nonlinear model and improve prediction accuracy. Support vector machines refer to finding the optimal classification hyperplane to establish a classification model and improve prediction reliability.

During the process of oil well fracturing production prediction, model construction methods can improve prediction accuracy and reliability. For example, through multiple linear regression, a linear model can be established to describe the relationship between multiple variables and predict oil well production; through neural networks, a nonlinear model can be established to improve prediction accuracy; through support vector machines, a classification model can be established to improve prediction reliability. These methods provide technical support for the construction of oil well fracturing production prediction models.

3.3 Result Presentation Techniques

Result presentation is the key step of visualization design, aimed at visually presenting prediction results to improve user understanding and decision-making capabilities. Result presentation techniques mainly include chart design, dynamic interaction, and three-dimensional visualization. Chart design refers to designing various charts, such as line charts, bar charts, pie charts, etc., to visually present prediction results. Dynamic interaction refers to designing interactive interfaces, such as sliders, buttons, etc., allowing users to dynamically adjust parameters and view prediction results under different conditions. Three-dimensional visualization refers to designing three-dimensional models, such as geological models, fluid models, etc., to stereoscopically present prediction results.

During the process of oil well fracturing production prediction, result presentation techniques can improve user understanding and decision-making capabilities. For example, through chart design, prediction results can be visually presented for user understanding and analysis; through dynamic interaction, users can dynamically adjust parameters and view prediction results under different conditions, improving decision-making flexibility and accuracy; through three-dimensional visualization, prediction results can be stereoscopically presented to enhance user visual experience and decision-making support capabilities.

4. Application of Visualization Design in Oil Well Fracturing Production Prediction

4.1 Selection and Design of Visualization Tools

In oil well fracturing production prediction, choosing the appropriate visualization tools is key to achieving efficient visualization design. Common visualization tools include Matplotlib, D3.js, Tableau, etc. Matplotlib is a Python-based plotting library suitable for drawing static charts. D3.js is a JavaScript-based visualization library suitable for designing dynamic interactive charts. Tableau is a commercial data visualization tool suitable for complex data visualization analysis.

When selecting visualization tools, factors such as data type, scale, and user needs should be considered. For example, for small-scale static data, Matplotlib can be chosen for chart drawing; for large-scale dynamic data, D3.js can be chosen for interactive chart design; for complex data analysis and display, Tableau can be chosen for visualization analysis. By reasonably selecting and designing visualization tools, the visualization effect and user experience of oil well fracturing production prediction can be improved.

4.2 Evaluation of Visualization Effects

The evaluation of visualization effects is an important link to ensure the quality of visualization design. Evaluation indicators mainly include the accuracy, readability, and interactivity of visualization. The accuracy of visualization refers to whether the results of charts and models truly reflect the characteristics and laws of data. Readability refers to whether the design of charts and models is clear and easy to understand, facilitating user understanding and analysis. Interactivity refers to whether the design of charts and models has good interactive functions, allowing users to dynamically adjust parameters and view results.

When evaluating visualization effects, user testing and feedback can be used for evaluation. For example, by inviting users to test and collecting their opinions and suggestions, the accuracy, readability, and interactivity of visualization can be evaluated; by analyzing user operation records and behavioral data, the usage effect and user experience of visualization can be evaluated. By continuously optimizing and improving visualization design, the visualization effect and user satisfaction of oil well fracturing production prediction can be enhanced.

4.3 Application Case Analysis

In oil well fracturing production prediction, the application case analysis of visualization design can provide reference and inspiration for practical applications. By analyzing typical application cases, the actual effects and application value of visualization design can be understood. For example, in the fracturing production prediction of an oilfield, by applying multiple linear regression and neural network models combined with visualization design techniques, the production of oil wells was successfully predicted, and the prediction results were intuitively displayed through charts and three-dimensional models, improving user understanding and decision-making capabilities.

Through application case analysis, the experiences and lessons of visualization design can be summarized, and problems and improvement directions can be found. For example, by analyzing user feedback and operation records, the shortcomings and improvement space of chart design can be found; by analyzing the accuracy and reliability of prediction results, the shortcomings and optimization directions of model construction can be found. By continuously summarizing and improving, the level and application effect of visualization design for oil well fracturing production prediction can be enhanced.

5. Conclusion and Future Directions

5.1 Summary of Research Achievements

This paper has explored the visualization design of oil well fracturing production prediction models, enhancing the intuitiveness and comprehensibility of prediction results. The research content includes the theoretical basis of oil well fracturing production prediction models, the methodology of visualization design, and the application of visualization design in oil well fracturing production prediction. By elaborating on geological mechanics, fluid mechanics, and statistical principles in detail, the theoretical basis of oil well fracturing production prediction models was clarified; by elaborating on data preprocessing, model construction, and result presentation techniques in detail, the methodology of visualization design was clarified; by elaborating on the selection and design of visualization tools, the evaluation of visualization effects, and application case analysis in detail, the application of visualization design in oil well fracturing production prediction was clarified.

5.2 Future Research Directions

Future research can be deepened in the following aspects: Firstly, further optimize oil well fracturing production prediction models to improve prediction accuracy and reliability. Secondly, explore and apply more advanced visualization technologies, such as virtual reality and augmented reality technologies, to enhance visualization effects and user experience. Finally, strengthen interdisciplinary research, combining knowledge and methods from geology, engineering, and data science to promote the innovation and development of oil well fracturing production prediction models and visualization design.

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