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Research on Seismic Signal Enhancement Method Based on Deep Learning

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Abstract: *At present, human beings are increasingly dependent on oil and gas energy. Due to the influence of a series of factors such as exploration technology and natural environment, in the process of actual oil and gas exploration technology, the collected seismic data usually has the problem of low sampling rate. The lower sampling rate of seismic data may cause spatial aliasing in migration imaging, resulting in inaccurate exploration. Therefore, in order to carry out more accurate oil and gas exploration, the seismic signal enhancement method also puts forward higher requirements. In this paper, the seismic signal enhancement will be realized by seismic data channel interpolation. A seismic trace interpolation method based on generative adversarial network is proposed to realize it. The traditional seismic trace interpolation is generally carried out based on complex mathematical transformation or certain assumptions, in order to solve the problems existing in the traditional seismic trace interpolation method. This paper will use the generative adversarial network model in deep learning to combine the generative adversarial network with the residual network, and the loss function is the sum of the Wasserstein distance and the content loss. The optimized generative adversarial network can better realize the interpolation of seismic traces, and the spatial aliasing frequency has been suppressed. Therefore, the enhancement of seismic signals can be better achieved, and theoretical support for accurate exploration can be provided.*

Keywords: *Deep Learning, Generative Adversarial Networks, Seismic Trace Interpolation*

1. Introduction

With the rapid development of modern society, scientific and technological civilization has reached a new height, and at the same time, human consumption of resources is also increasing. Oil, natural gas, etc. are the most important energy sources, and all aspects of life are now inseparable from these energy sources[1]. With the rapid development of modern technology, the efficiency of oil and gas extraction has gradually accelerated. china is one of the major oil and gas producers in the world today. Compared with the speed of china economic development, the output of oil and gas cannot meet the needs of china economic development, so it still needs to rely on the import of foreign oil and gas. China has abundant resources, but they are not fully exploited. From the perspective of energy security, improving the development of china oil and gas exploration is a problem that needs to be solved in the field of exploration.

In the actual exploration process, in order to accurately explore the exact location of oil and gas resources, the requirements for exploration technology will be very high. In the actual seismic data acquisition process, the artificial method is used to excite the seismic waves in the exploration area, and then the excited seismic waves are received by the geophone[3]. During the propagation process of seismic waves, different types of reflected waves will be reflected when they pass through different geological structures and strata, and then the surface geophone can collect the reflected seismic waveforms. Infer the location information of underground oil and gas resources. Due to various reasons of geographical conditions, it is possible to block the placement of the geophone. In order to improve the efficiency of oil and gas exploration and reduce the cost of oil and gas exploration, the seismic data acquisition and observation system is usually designed with a larger seismic trace spacing. Shifted imaging may produce serious aliasing, which has a great impact on the interpretation of seismic data. To overcome the spatial aliasing in the seismic data acquired in the actual oil and gas exploration process, the use of seismic data channel interpolation will be a very important method.

2. Related Principles of Seismic Signal Enhancement

Seismic signal enhancement is achieved by using generative adversarial network to achieve seismic trace interpolation enhancement. Provide high-density, high-resolution seismic data for oil and gas exploration. The method and principle of seismic trace interpolation, the principle of convolutional neural network in deep learning, and the principle of generative adversarial network are adopted.

2.1. Deep Learning

In recent decades, with the explosive growth of data, in order to solve the problems caused by the large amount of data, deep learning has developed rapidly. The essence of deep learning is a multi-level representation learning method. Deep learning is based on many simple but non-linear structures. In each layer of network structure, each network module converts the input representation into a more abstract and advanced level. characterization. Then the network model can learn many structural features of the data model according to various feature combination methods of each layer. The following article will introduce the commonly used neural network models and theoretical foundations in detail.

2.2. Convolutional Neural Networks

Convolutional Neural Network (CNN)is a typical feedforward network model structure. The network model updates the weight parameters in the network by means of backpropagation. Compared with the traditional network model, the convolutional neural network has many advantages. For example, in the training process of the convolutional neural network, the convolutional layer uses the local receptive field and weight sharing to train the network model. Through the improvement of these methods, the parameters in the network training process can be reduced compared with the original neural network model, and then Improve the efficiency of network model training..

2.3. Generative Adversarial Networks

Generative Adversarial Networks (GAN) is a deep learning model and one of the most promising methods for unsupervised learning on complex distributions in recent years. The model produces fairly good outputs through mutual game learning of (at least) two modules in the framework: Generative Model and Discriminative Model. In the original GAN theory, both G and D are not required to be neural networks, but only functions that can fit the corresponding generation and discrimination. But in practice, deep neural networks are generally used as G and D.

2.4. Seismic Trace Interpolation Principle

In the process of seismic data acquisition, in order to reduce the cost and workload of field acquisition, the distance between the geophones in the seismic data acquisition process is relatively large, resulting in a lower spatial sampling rate, which will lead to spatial aliasing. phenomenon occurs, which affects the imaging effect of seismic migration.

The essence of seismic trace interpolation is to insert the correct seismic trace in the original low sampling rate seismic data by using the appropriate seismic data trace interpolation method. Seismic trace interpolation technology can restore more accurate strata distribution underground, which is based on factors such as continuity and predictability of the underground medium [2]. The seismic trace interpolation technology is similar to the situation in the signal processing field. In the actual oil and gas exploration process, we discretize the continuously changing underground structure in a sparse way, and then use the discretized data to infer the distribution of the underground structure. Therefore, trace interpolation can be achieved through complex relationships between adjacent traces. For example, attribute information such as velocity, amplitude, and frequency between adjacent seismic traces can determine the middle seismic trace, and then realize the interpolation of seismic traces, achieve the purpose of eliminating spatial aliasing, and provide more accurate geological structure for oil and gas exploration.

2.5. Seismic Trace Interpolation Method

With the development of oil and gas exploration technology, scholars at home and abroad have proposed many seismic trace interpolation methods. The commonly used seismic trace interpolation methods mainly include the following three.

2.5.1. Seismic Trace Interpolation in f-x Domain

The basic theory of the seismic trace interpolation method in the f-x domain is to first transform the seismic data into the seismic data in the f-x domain by means of Fourier transform. Then the prediction operator is obtained according to the number of events in the seismic data, and the interpolation operator is obtained according to the relationship between the prediction operator and the interpolation operator. Finally, the interpolated seismic trace is obtained according to the least square method. This method can interpolate better results when there are few curved events in the seismic data. However, the calculation process of the seismic trace interpolation method is complicated, resulting in low calculation efficiency in the interpolation process.

2.5.2. T-X Domain Prediction Error Filter Interpolation

The seismic trace interpolation method is to calculate the prediction error filter through the known seismic data, and then multiply the prediction error filter by its conjugate to calculate the inverse covariance matrix. interpolated data. Seismic gathers can be accurately interpolated by this method, but the interpolation algorithm uses two least squares operations in the process of seismic trace interpolation. As a result, the calculation process of this seismic trace interpolation method is cumbersome, and this method has a significant impact on the seismic trace interpolation effect containing noise data. When the noise is large, the interpolation effect is relatively poor.

2.5.3. Seismic Trace Interpolation of Sinc Technology

The seismic trace interpolation method is to transform the original seismic data into the frequency wavenumber domain. Then, the transformed data is expanded along the direction of the wavenumber domain by zero-filling, so that the size of the seismic data is twice the size of the original seismic data. The interpolated seismic data. Sinc based the seismic data trace interpolation method is more efficient, but the disadvantage of this method is that it cannot accurately interpolate the data containing spatial aliasing.

3. Research on Seismic Trace Interpolation Method Based on Generative Adversarial Network

Traditional seismic trace interpolation is generally based on certain assumptions, such as the classical f-x domain seismic trace interpolation is based on the assumption of linear event axis. In the field of deep learning, the generative adversarial network method comes from the data itself, and uses its learning ability to fit the complex functional relationship between different data, thereby realizing the prediction of missing seismic data. In this paper, considering the complex relationship between seismic traces, the residual network with strong feature extraction ability is applied to the generative adversarial network model, and the objective function of the generative adversarial network is optimized at the same time[5].

3.1. Network Architecture

The purpose of Generative Adversarial Networks is to achieve seismic trace interpolation[4]. Therefore, a well-designed generative adversarial network architecture is especially important for the training of network models. Since the actual seismic data contains complex stratigraphic information, in order to better fit the complex relationship of waveform characteristics between different seismic traces, we apply the deep residual network to the generative adversarial network architecture.

3.2. Model Loss Function Construction

In order to better train the generative adversarial network model proposed in this paper, in order to better realize the interpolation of seismic data traces. The network model architecture designed in this paper includes the loss function of the generative network model and the loss function of the discriminative network model in the training process. Through the joint action of these two loss functions, the stability and effectiveness of the network in the training process can be guaranteed. This article will be based on Wasserstein distance to construct a loss function to solve the vanishing gradient problem in the original generative adversarial network.

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3.3. The Overall Process of the Algorithm

- Training set (raw seismic data and downsampled seismic data);
- The trace interpolation seismic data and the original data generated by the generative adversarial network are used as the input of the discriminant network;
- The discriminant network determines whether the generated trace interpolation seismic data or the original seismic data;
- Network direction propagation to update the generated network and discriminate network parameters;
- Use the trained network model for seismic trace interpolation;
- Analysis of results.

Compared with the traditional seismic trace interpolation method, the generative adversarial network seismic trace interpolation method is more dependent on the characteristics of the data itself. By designing the network model architecture, the model architecture can automatically learn the relationship between the data, so that the relationship between the seismic traces can be better discovered. , and then realize seismic trace interpolation.

4. Conclusions

This paper proposes and implements a method of seismic trace interpolation based on deep learning. The generative network architecture, discriminative network architecture and loss function of optimizing generative adversarial network OGAN are introduced. According to the seismic trace interpolation method, the corresponding seismic trace interpolation measurement index is established, and then the seismic trace interpolation results are analyzed from different angles. The method in this paper is applied to the synthetic seismic data and the actual seismic data of the work area, and the seismic trace interpolation results are compared with the traditional f-x domain seismic trace interpolation and convolutional neural network seismic trace interpolation results. The synthetic seismic data is used to verify the rationality of the method in this paper to realize the interpolation of seismic traces, and the practical seismic data is used to verify the practicability of the method in this paper. The deep learning algorithm has a good effect on the seismic data with large seismic data track spacing, and the spatial aliasing can be effectively suppressed, thereby realizing the enhancement of the seismic signal.

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