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3D Fault Identification Based on Improved U-Net with Multi-Scale Feature Fusion

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In the fields of geological research and engineering applications, fault identification is of great significance for understanding geological structure evolution, predicting geological disasters, and guiding resource exploration and development. Traditional fault identification methods based on manual interpretation and seismic attributes struggle to meet the requirements in terms of efficiency and accuracy when faced with complex geological conditions and massive amounts of data. With the development of deep learning technology, convolutional neural networks have demonstrated excellent performance in image recognition and segmentation tasks. However, the multi-scale characteristics of faults, that is, the fault structures in seismic images are diverse in size, shape, and complexity, pose severe challenges to image recognition. This paper innovatively proposes a fault identification method based on an improved U-Net neural network. Focusing on the multi-scale characteristics of faults, it aims to enhance the accuracy and robustness of fault identification. The model introduces a multi-scale feature fusion mechanism, skillfully integrating encoder feature maps with different spatial resolutions, which significantly improves the ability to express fault features. In addition, in view of the insufficient representativeness of synthetic datasets, this study adopts data augmentation techniques, performing operations such as rotation, flipping, and scaling on the training data to effectively expand data diversity and enhance the generalization ability of the model. Experimental results show that when the improved U-Net model is tested on the publicly available F3 seismic data of the Dutch North Sea and the data of an oilfield in the Junggar Basin, China, compared with the traditional U-Net model, it has achieved significant improvements in key evaluation indicators such as recognition accuracy, recall rate, IOU, and PR curve. Especially in complex geological backgrounds, the improved model can more accurately identify the location and shape of faults, providing a more reliable and efficient fault identification technical means for fields such as geological structure research, oil exploration, and underground engineering construction. It has important theoretical significance and practical application value.