Seismic Horizon Interpretation with Deep Learning: a case study in Santos Basin

João P. Gomes[1], José L. Silva[2], Paulo Vidigal[1], Paulo Barros[2,3], Alexsandro G. Cerqueira[2] - [1]Grupo de Estudo e Aplicação de Inteligência Artificial em Geofísica (GAIA.UFBA), [2]Oxaala Ltda., [3]Petrobras

This paper was prepared for presentation during the 4th Joint SBGf/SEG Workshop on Machine Learning held in Rio de Janeiro, Brazil, 03-04 December 2024.

Abstract

Seismic horizons, as key reflection surfaces within seismic amplitude volumes, play a crucial role in interpreting subsurface geological formations. They enable geoscientists to map the earth's structures and understand tectonism and sediments' spatial and temporal dynamics. Accurate identification of seismic horizons is fundamental in detecting amplitude variations linked to geological anomalies, such as faults or reservoirs, making them vital for effective exploration. Through precise horizon mapping, interpreters can gain insights into the history and processes that influence the formation of subsurface structures, thereby aiding in geological modeling and hydrocarbon exploration.

Traditional seismic interpretation has relied heavily on manual methods, particularly with 2D seismic profiles. However, the expansion of 3D seismic surveys has revealed the limitations of these methods, especially when dealing with vast datasets or complex geological settings. Auto-tracking algorithms have been introduced to assist in horizon identification by using seed points and tracing reflections automatically across large datasets. Despite these advancements, such methods often face challenges across discontinuous areas like faults or chaotic reflections. Techniques incorporating 3D structural attributes and global optimization strategies have been proposed but still require manual intervention in regions with non-stratified or noisy data.

The resurgence of deep learning, particularly with convolutional neural networks (CNNs), has transformed seismic interpretation by offering superior performance over traditional techniques. Earlier attempts to use neural networks for seismic tasks were limited by computational capacity, but recent advancements have enabled deep learning models to achieve more accurate and efficient horizon tracking. CNNs, especially U-Net architectures, allow for multi-scale processing, improving the ability to predict high-resolution horizon boundaries in complex geological settings. Integrating attention mechanisms in these models further enhances performance by focusing on the most relevant features, making deep learning a powerful tool for seismic horizon interpretation.

This work proposes a novel approach to seismic horizon segmentation using several deep learning architectures focusing on the Santos Basin's complex geology. We use the Intersection of Union (IoU) metric to evaluate the model, and It was possible to notice that the methodology allowed a more accurate horizon segmentation, while manual picks inform the model to handle uncertainty in horizon locations. The approach aims to improve both the accuracy and efficiency of seismic interpretation, reducing the cognitive load on interpreters and advancing automated horizon detection in challenging environments.