Submission code: 0G9YL0R4GN

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Why predicting velocity models from real seismic shots is a challenge AI should avoid

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Introduction

An accurate estimation of velocity models is a central aspect of making a good seismic image. The Full Waveform Inversion (FWI) is state-of-the-art for the Velocity Model Building (VMB), which, in turn, presents several challenges, such as the linear nature of inversion, the cycle skip problem, and the lack of appropriate data (low frequencies, long offsets, and wide azimuths), which can lead to spurious results. Besides the uncertainties in the process, another key aspect of a velocity model build flow is its long execution time (order of months) and the high level of human curation required to prevent the aforementioned inversion problems.

With the rise of numerous AI applications in geosciences, deep learning methods have been intensively explored over the last five years to address the VMB problem. However, there are scarce applications for real seismic data. Recently, the proposal of a Kaggle challenge involving the VMB problem drew attention from the academic community. In this challenge, the proposed data and approach consisted of using pairs of simulated seismic shots and the correspondent velocity models. In the pure supervised approach, which is successful in the problem design proposed, the trained neural network would be able to predict the complete velocity model from the seismic shots in a single inference pass, reducing the computational and uncertainty of the conventional VMB flow immensely.

Method and/or Theory

One question that arises when analyzing the DL literature for the VMB problem is why there are few applications and why some results are obtained even with poor seismic shot sampling and seismic acquisition designs, which seem insufficient for reconstructing the desired velocity model. This work will review various deep-learning approaches proposed in the literature to solve the VMB problem, progressing from supervised approaches to physics-informed and diffusion methods. The revision of the methods will focus on developing feasible roadmaps to obtain a solution applicable to real seismic datasets, as well as the potential benefits and hazards of adopting each approach. This review will also discuss why some experimental designs, such as the one proposed in the challenge, are almost infeasible to extend to real-world cases.

Results and Conclusions

By analyzing the various approaches presented in the literature that address the VMB problem, it was possible to identify which methods can be extended to real datasets. The difficulties of each chosen approach will be discussed, along with the features desirable in the problem design to harness this potential application. Another question to be raised here is to identify which problems are the real bottlenecks in the modern VMB flow and how to employ deep-learning solutions to address these bottlenecks.