Enhancing automatic first-break picking in time-lapse OBN data with convolutional neural networks

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Accurate first-break picking is an essential step for seismic data processing, serving as a fundamental prerequisite for tasks such as static corrections and the estimation of subsurface velocity. In this study, we propose an approach based on one-dimensional convolutional neural networks (CNNs) for first-break picking in time-lapse ocean bottom node (OBN) data. Conventional methods for first-break picking often encounter challenges in handling complex subsurface structures and noisy environments, resulting in suboptimal outcomes. Such pickings usually need to be manually corrected for desirable results, which is a laborious and time-consuming task. To address these limitations, we adopt a robust framework based on CNNs, which excel at capturing spatial and temporal dependencies in seismic data. In our study, we examine the efficacy of CNN-based automatic picking in OBN synthetic datasets, a task that can be particularly challenging due to the significant spacing between nodes. Our approach appears to offer significant advantages over traditional automatic picking methods. By leveraging the automatic feature extraction capability of CNNs, the need for manual feature engineering might be significantly attenuated, reducing subjectivity and labor. The CNN-based method demonstrates resilience against various noise sources, including acquisition-related noise and ambient noise, thereby enhancing the reliability of first-break picking results in realistic scenarios. Moreover, time-lapse data complicates first-break picking as non-repeatability is inherent in time-lapse seismic. These acquisitions are primarily used to monitor specific areas of interest such as oil reservoirs, aiming for greater repeatability between the baseline (initial acquisition) and subsequent acquisitions (monitors). Here, we also investigate the possibility of training CNNs in baseline datasets and, later, applying the obtained models to automatically determine the first-break arrivals in monitor datasets. The proposed CNN-based and the conventional Modified Energy Ratio (MER) methods are independently applied on a diverse synthetic seismic dataset, and the obtained first-break picking results are compared for evaluation purposes. We performed two different tests to evaluate the quality of first-break picking with CNNs: (i) for a single OBN seismic acquisition, we trained the CNN with manual picking performed with a seismic data processing software in a subset of the available traces, and used it to infer the first-break times of the remainder traces; and (ii) we trained the CNN with the results from a manual picking performed in a baseline time-lapse OBN acquisition, and inferred the first-break times in a monitor acquisition, corrupted by time-lapse non-repeatability perturbations in seawater velocity and source/receiver positioning. These tests were performed on synthetic datasets, generated by numerically simulating the forward acoustic wave propagation with a velocity model estimated from the Brazilian pre-salt. The results demonstrate that the proposed method yields more accurate first-break pickings compared to existing automatic picking techniques. The performance obtained by our approach in this specific context showcases its enhanced accuracy, noise resilience, and adaptability to complex subsurface structures. Further studies must be conducted to evaluate the possible benefits of performing CNN-based automatic picking of first-break times in more complex field seismic datasets.