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Real-time Identification of Passive Seismic Events Using a PRM system in the Deep Offshore Santos Basin

Victor Muniz (COPPE / Federal University of Rio de Janeiro), Adriana Triques (Petróleo Brasileiro S.A), João Souza Filho (COPPE / Federal University of Rio de Janeiro), Julio Vargas (National Laboratory of Scientific Computing), Thomas Browaeys (TotalEnergies Brasil), Wallace Abreu (COPPE / Federal University of Rio de Janeiro), Natanael Junior (COPPE / Federal University of Rio de Janeiro), Alexandre Esukov (COPPE / Federal University of Rio de Janeiro), Leandro Gomid (Petróleo Brasileiro S.A)

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Introduction

Permanent Reservoir Monitoring (PRM) systems are increasingly used in the oil and gas industry for long-term seismic monitoring due to their ability to detect low levels of time-lapse seismic signals. They are designed to enhance oil recovery, production, and operational safety. Their advantages lie in the high repeatability of seismic acquisitions and real-time data access. Beyond active seismic campaigns, PRM systems enable continuous passive seismic monitoring, which can provide valuable information about the reservoir over time. In passive mode, these systems can detect a wide range of events of interest, typically associated with natural, operational, or biological factors. This task is challenging, as it requires recognizing complex signal signatures across numerous sensors and readouts in real-time. An additional layer of complexity arises from the monitored environment itself, whose characteristics often evolve over time, requiring the system to be flexible and adaptable to new operational scenarios. To meet these demands, PRM systems must employ advanced signal processing strategies to extract features from sensor data, along with robust detection and classification models to reliably identify relevant events. This work focuses on ongoing research efforts to develop and deploy a scalable, robust, and adaptive real-time detector, along with an offline classifier, capable of identifying both natural and man-made events in PRM data acquisitions.

Method and/or Theory

The detection system comprises a signal processing pipeline, multiple detectors, and a decision fusion mechanism. The processing pipeline produces meaningful time- and frequency-domain signal descriptors - such as energy, entropy, spectral density, spectral centroid, and spectral flatness – computed over overlapping sliding windows. Real-time detectors operate by measuring the similarity between raw signal signatures and signal descriptors patterns against a signature bank generated by a dictionary-extraction algorithm. Individual decisions from each sensor are then fused by considering the spatial distribution of PRM sensors, the temporal coherence among detections, and the persistence of each alarm. In parallel, the classification system processes sensor-fused data - guided by the detection outputs - using specialized neural networks tailored to each target class. These networks are trained with public datasets that are synthetically propagated through an acoustics simulation framework. To support system design and validation, a comprehensive study is being conducted using real passive data collected from the Mero field, acquired through an array of Ocean Bottom Nodes (OBNs).

Results and Conclusions

An initial analysis involving OBN signals and a basic time-frequency processing pipeline was conducted over a two-month evaluation period, during which the field experienced multiple operational conditions, including offloading, drilling activities, and gas injection, among others. This analysis focused on inferring the spectral signatures of hydrophone signals from different OBNs. Different strategies for detector deployment and their statistical calibration are currently under evaluation. Initial results indicate that adaptive activation thresholds may be necessary due to signal fluctuations, underscoring the need for further investigation into suitable calibration procedures. Additionally, studies and preliminary experiments on decision fusion are in progress, as well as the classification pipeline. These early findings are promising, suggesting that this investigation may lead to the development of a robust and innovative tool for real-time platform monitoring.