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DIAGNOSIS OF ROTATING MACHINERY FAILURE MODES IN THE O&G INDUSTRY VIA QUANTUM MACHINE LEARNING

Lavínia Maria Mendes Araújo[1*]
Isis Didier Lins[1]
Caio B. S. Maior[1]
Márcio J. C. Moura[1]
Enrique López Droguett[2]

ABSTRACT

Rotating machines are crucial equipment in the Oil and Gas (O&G) industry that operate in challenging environments subjected to high temperatures, fatigue, and heavy loads. Vibrational analysis is now the industry standard for evaluating the conditions of these types of equipment. Traditional Prognostic and Health Management (PHM) methods for diagnosing failure modes involve feature extraction using signal processing techniques and defect classification utilizing Machine Learning (ML) and Deep Learning approaches. However, Quantum Computing (QC) has recently gained significant attention in the literature for promoting problem-solving improvements. Quantum Machine Learning (QML) combines QC techniques with classical ML models, with qubits or quantum bits being the smallest quantum units. Qubits can be in states "0", "1", or a linear combination of the two called superposition. Moreover, entanglement operations allow strong correlations to be established between qubits, irrespective of their distance. Therefore, this study aims to investigate and adapt QML models to perform PHM, particularly in diagnosing the failure modes of equipment components in the O&G industry. We present models that employ combinations of the Variational Quantum Eigensolver framework with three distinct entanglement gates (CNOT, CZ, and iSWAP), as well as varying the number of quantum circuit layers. In addition to the intricate analyses conducted by the authors in a previous study, this paper aims to compare two distinct data preprocessing approaches. Specifically, the first approach involves processing the data in the time domain, while the second approach utilizes the frequency domain via a Fast Fourier Transform. Furthermore, an alternative encoding method, known as amplitude encoding, will be tested. Lastly, the impact of quantum noise will be evaluated to ascertain the viability of the proposed models on quantum computing hardware. We use two datasets, named Case Western Reserve University and Jiangnan University that contain information on 10 and 12 failure modes, respectively. The results demonstrate that quantum approaches have higher accuracy than classical models, indicating the potential of QML in the O&G industry. As quantum technologies advance, the O&G industry can benefit significantly from QML, potentially leading to a more efficient diagnosis than those currently performed through classical ML models. This study in Production Engineering contributes to improved failure diagnosis, predictive maintenance, equipment lifespan optimization, and advanced data analysis techniques. These developments enhance operational efficiency, reduce costs, increase production system reliability, and improve service safety and environmental sustainability.

Keywords: Quantum Machine Learning; Prognostic and Health Management; Failure mode diagnosis, Vibration Signal; Rotating Machinery.

[1] Universidade Federal de Pernambuco (UFPE)
[2] University of California Los Angeles, USA
*Corresponding author: Lavínia Maria Mendes Araújo (lavinia.mendes@ufpe.br)