Well Drilling Location Scheduling Using Deep Reinforcement Learning and Graph Neural Networks in Oil and Gas Extraction Projects

Context of the research

The Oil and Gas (O&G) extraction industry operates in highly dynamic and uncertain environments, where factors such as geological variability, fluctuating commodity prices, and regulatory changes can significantly impact project outcomes. Field development planning entails the decisions about the placement and design of wells and other critical infrastructures, with the objective of optimizing the process of extraction of subsurface resources. In complex subsurface systems, traditional rule-based or optimization-based approaches often fail to capture the intricate dependencies between geological features, well interactions and uncertainty in the environment. Poor drilling decisions can lead to suboptimal resource recovery, excessive costs or unintended environmental consequences.

Graph Neural Networks (GNNs) offer a powerful way to represent subsurface structures, where spatial and hydraulic relationships between locations can be naturally modelled as graphs. Deep Reinforcement Learning (DRL) complements this by learning adaptive strategies for sequential drilling decisions under uncertainty, balancing short-term gains and long-term system impacts.

This research proposes integrating GNNs and DRL to enable intelligent, risk-informed scheduling of drilling activities.

Objective of the research

This thesis aims to develop a unified framework combining GNNs and DRL to support risk-aware and efficient drilling location scheduling. The GNN encodes the geospatial and hydrogeological characteristics of the subsurface system, whereas the DRL agent learns policies that optimize the drilling sequence, considering both operational objectives and risk metrics.

The research activities include:

- Reviewing literature on DRL and GNNs in geospatial and drilling-related applications.
- Modelling subsurface environments as graphs.
- Developing a GNN to encode system state and risk-relevant features.
- Training a DRL agent to learn a drilling policy that balances exploration, risk mitigation and performance.
- Validating and benchmarking the approach using synthetic datasets and benchmarks.
- Evaluating the strengths, limitations, and scalability of the developed framework.
- Writing of scientific papers as chapters of the thesis.

Case study

Drilling of Wells in Oil and Gas Reservoirs

In oil and gas exploration and development, scheduling the order and location of well drilling directly influences the recovery factor, production efficiency and safety. Drilling into over-pressurized or geomechanically unstable zones can cause blowouts or damage to adjacent wells. Given the interest of the O&G industry in drilling scheduling, the Olympus challenge was launched to provide a basis for assessing the performance of methods for drilling scheduling optimization. This challenge provides 50 possible realizations of the parameters describing the geological properties of a reservoir and requires optimizing the drilling schedule with the objective of maximizing the expected Net Present Value (NPV).

Collaborations

The work will be performed in the Laboratory of Analysis of Systems for the Assessment of Reliability, Risk and Resilience (LASAR^3, www.lasar.polimi.it) of Politecnico di Milano. Possible collaboration with ENI S.p.A.

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