Well Drilling Location Scheduling Using Deep Reinforcement Learning and Graph Neural Networks for Contaminant Remediation in Nuclear Sites

Context of the research

Groundwater contamination is a pervasive problem that can affect humans and the environment worldwide. Many industrial sites, e.g. nuclear and chemical facilities, presents a range of health and environmental risks because of their large size, prominence and contamination with harmful chemicals, as a result of various industrial operations. Efficient and risk-aware scheduling of drilling operations is a critical challenge in environmental remediation. 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 contaminant 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 in nuclear sites. 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 a scientific article as a chapter of the thesis.

Case study

Drilling of Wells for Radioactive Contaminant Removal in Nuclear Sites

Contaminant removal in nuclear sites requires that wells are strategically drilled to extract released radionuclides or contain them from dispersing. Poor placement of wells can spread contamination or miss key plumes.

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 collaborations with the Department of Civil and Environmental Engineering of Politecnico di Milano.

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