AI-Guided Noise Reduction for Urban Geothermal Drilling

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1 Extended Abstract

Urban geothermal energy production is increasingly recognized as a pivotal component in achieving global climate goals. However, the deployment of geothermal technology in urban areas is not without challenges, particularly the significant noise pollution generated during drilling processes. Current methods for mitigating this issue are largely manual and often inadequate for maintaining noise levels within legal urban limits. In densely populated areas, continuous deep drilling operations required for geothermal energy can severely disrupt local communities. Legal requirements often cap noise levels at 35dB during nighttime, posing a substantial challenge given the 24/7 operational needs of these projects. Current solutions, including temporal shifting of operations and physical barriers, provide limited relief.

This research introduces an application of artificial intelligence to overcome the constraints of traditional noise reduction techniques in geothermal drilling. By integrating Deep Reinforcement Learning (DRL) with generative neural network models, we dynamically suggest drilling parameters based on continuous feedback. Our system utilizes two models trained on real-world data: one forecasting noise outcomes and the other predicting drilling scenarios. A DRL model uses these simulations to learn optimal drilling strategies that minimize noise while maintaining drilling efficiency. The system's performance is planned to be further refined through real-world application, aiming to ensure its effectiveness across various urban geothermal sites.

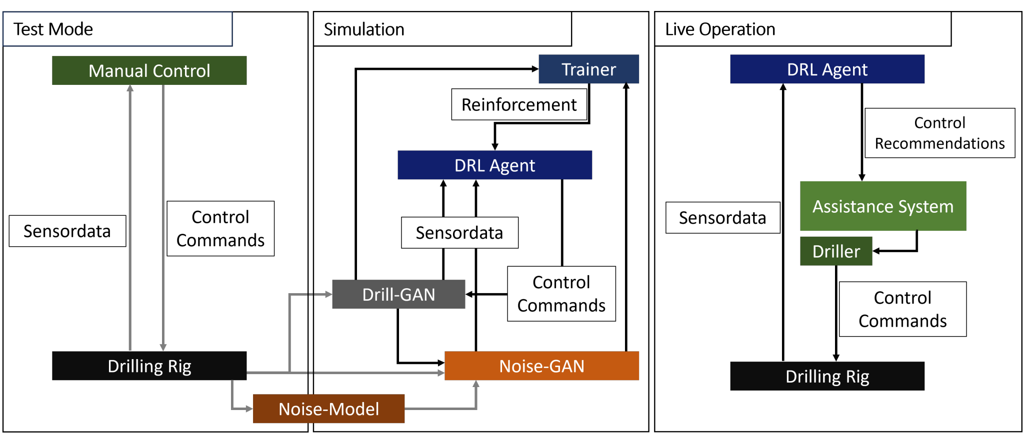
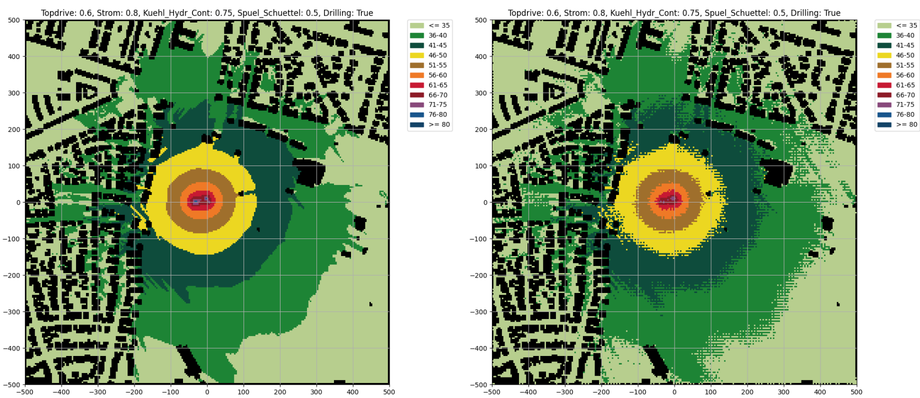


Fig. 1: Architecture of the AI models during the development stages Test Mode, Simulation and Live Operation.

Implementation Prototypes: The project is structured into three distinct prototypes, each illustrated in Figure 1. In *Test Mode*, generative models simulate sound propagation, drilling rig behaviour and predict drilling progress from specific states and commands. In the *Simulation* phase, a DRL model uses input from generative models to learn the control of the simulated drilling rig through reinforcements to provide operation recommendations, which then are validated against real-world scenarios. Finally, in *Live Operation*, the DRL system operates as an assistant that recommends strategic control changes during the drilling process. The human operators stay in control, providing oversight and evaluating AI-recommended commands. The system will be further improved by continuously learning from actual data and human feedback.

Simulation vs. Generative AI: Building on our previous work, where we evaluated the effectiveness of generative models for predicting sound propagation [1], we generated over 15,000 data samples using the *NoiseModelling v4* framework [2], compliant with *CNOSSOS-EU* standards [3]. Each sample was defined by unique drilling parameters. This simulation data serves as the foundation for three different generative image-to-image models: **GANs** based on [4], **UNets** [5] and **DDPM diffusion** models [6]. Figure 2 visualizes how the GAN effectively interprets complex driller states, closely aligning predicted noise distributions with those from simulations. In addition, generative models significantly outperform traditional sound propagation simulations in processing speed, achieving up to a 50k factor improvement in runtime, with a mean absolute error of 0.55 dB in their predictions.



(a) Simulation (b) GAN Prediction

Fig. 2: Comparison of simulated sound propagation maps (a) and GAN-predicted noise distributions (b).

Using AI for dynamic noise reduction is anticipated to lower sound emissions from geothermal drilling operations, enhancing community tolerance and supporting broader acceptance of urban geothermal energy projects. This contributes to the economic viability of such projects and their potential impact on achieving climate targets. Integrating AI to control noise in geothermal drilling presents a transformative solution to one of the most pressing challenges facing urban renewable energy projects, promising not only to reduce noise pollution effectively but also to streamline drilling operations.

References

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