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Application of Artificial Intelligence and Machine Learning in a Nuclear Power Industry to Address Environmental Problems

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INTRODUCTION & AIM

Artificial Intelligence (AI) and Machine Learning (ML) are advanced computational techniques that have proven highly beneficial across various disciplines, including industry and academic research. The development of these technologies has sig-nificantly enhanced efficiency, productivity, and decision-making processes in indus-trial operations. Machine learning, a subset of computer science, emerged with the goal of data-based learning. Early ML methods focused on symbolic representation and knowledge-based learning, such as decision trees. Modern AI/ML methods have evolved through high-performance computing and large datasets, enabling high-performing predictive models capable of solving complex problems.

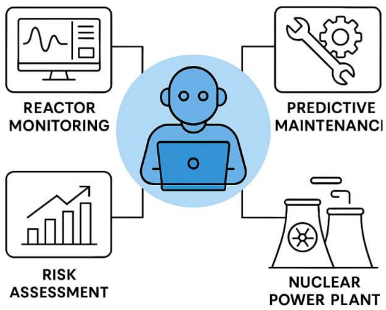

Figure 1: General aspects of the study reflecting AI and ML in the nuclear power industry

The poster aim to address the unresolved issues by providing a comprehensive analysis of recent research and developments in AI technologies within the nuclear sector (Fig. 1). It seeks to bridge the gap between theoretical potential and practical imple-mentation, offering insights into the challenges and opportunities of integrating AI into nuclear operations.

METHOD

The methodology of this research involves a detailed literature review of existing studies on AI applications in the nuclear industry. The research analyzes various AI methods, including neural networks, Gaussian processes, and Bayesian networks, and their applications in optimizing NPP operations. The study also includes an examination of the challenges and limitations faced in implementing AI technologies in nuclear energy.

Methods used in this study:

- Literature review: A systematic review of scientific articles, conference papers, and industry reports was conducted to collect comprehensive information on the application of AI in the nuclear sector.

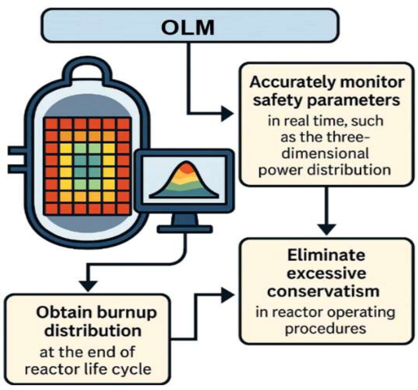

Figure 2: Goals of Online condition monitoring (OLM) technology

- Data analysis: Qualitative and quantitative data from the reviewed literature were analyzed to identify key trends, benefits, and challenges related to AI adoption.
- Case studies: Several case studies were reviewed to illustrate real-world examples of AI applications in the nuclear power industry.

RESULTS & DISCUSSION

ML algorithms can be divided into supervised and unsupervised learning. In supervised learning, the algorithm learns based on known values of the input data, while in unsupervised learning, the goal is to identify patterns or clusters in the data without known answers (Fig. 2). The most widely used methods in the nuclear indus-try are artificial neural networks (ANN), Gaussian processes (GP), and Bayesian net-works (Bn). Online condition monitoring (OLM) is a complex technology (Fig. 3) with interdisciplinary cross-over. OLM technology is used at NPPs to achieve three goals.

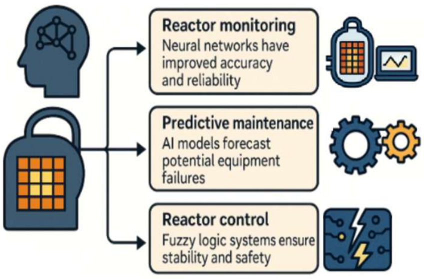

Figure 3: Integration of AI and ML into the operations of NPPs

The deployment of AI and ML in the nuclear power industry is transformative, promising significant enhancements in operational efficiency, safety, and reliability (Fig. 4). AI technologies have shown considerable success in reactor monitoring, predictive maintenance, and fault diagnostics.

To address these issues, the nuclear industry must invest in the development of robust data management practices and regulatory frameworks that facilitate AI integration.

Empirical studies quantifying AI's benefits and limitations are essential to build a solid evidence base for its adoption. By overcoming these challenges, AI can significantly contribute to the advancement of nuclear energy, promoting a safer, more efficient, and reliable power sector.

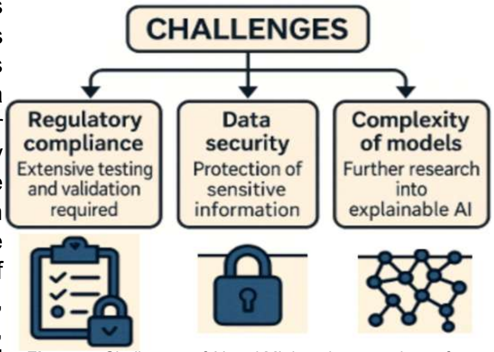

Figure 4: Challenges of AI and ML into the operations of NPPs

CONCLUSION

AI and ML have demonstrated considerable success across multiple domains within nuclear operations. Neural networks and fuzzy logic systems have enhanced the accuracy of reactor monitoring and stability of control processes. Deep learning models have facilitated real-time optimization of operational parameters and predictive maintenance, significantly reducing downtime and maintenance costs. However, the implementation of these systems is hindered by the lack of explainable AI frameworks and robust datasets necessary for training high-performance models. The findings underscore the transformative potential of AI and ML in the nuclear sector. To fully harness their capabilities, the industry must overcome existing barriers through targeted research in explainable AI, improved data governance, and adaptive regulatory frameworks.