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Short Communication

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Review of the State of Learning-Based Approach Research and Development in Nuclear Science and Engineering

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Abstract

The use of data-driven techniques by the nuclear technology industry to enhance asset availability, safety, and dependability has expanded. To build and implement such systems successfully, it is crucial to comprehend the foundational concepts between the disciplines. This study examines the foundations of artificial intelligence and the current state of learning-based approaches in nuclear science and engineering in order to assess the benefits and drawbacks of using such techniques for nuclear applications. This research focuses on applications in three significant decision-making and safety-related subfields. These include radiation detection, reactor health and monitoring, and optimization. Recent studies are examined, and the fundamentals of learning-based methodologies used in these applications are discussed. Additionally, as these techniques have improved in use throughout. Additionally, it is anticipated that learning-based methods will become more popular in nuclear science and technology as they have become more useful over the past ten years. As a result, it is important to understand the advantages and challenges of using such methodologies in order to improve research plans and recognise project risks and opportunities.

Keywords: Nuclear technology; Computer learning; Intelligent robots

Introduction

Information technology has been incorporated into numerous industries over the past few decades to enhance product and service innovation and creation. Nuclear science and engineering is not renowned for being a very inventive profession, however there is growing interest in upgrading the instrumentation of both new and old nuclear reactor technologies, as well as emerging technologies like nuclear robotics (Arndt, 2015). IAEA-TECDOC-1389, 2004) and to “enhance and detect subtle variation that could remain unnoticed” (IAEA-TECDOC-1363, 2003), including the use of artificial intelligence (AI) (IAEA-TECDOC-812, 1995), in order to “address obsolescence issues, to introduce new beneficial functionality, and to improve overall performance of the plant and staff.” [1-3].

Popular machine learning methods

In the literature, there are a number of AI approaches that can be found, including “old-fashioned AI” more contemporary AI and machine learning approaches, each with distinct advantages and disadvantages. Generally speaking, the majority of machine learning techniques seek out an empirical model f that learns from a training data matrix acquired from a system, where d is the number of variables involved and n is the number of training data samples. The pattern-recognition, credit assignment, and inductive inference problems are combined in machine learning. In supervised learning, updates aim to reduce an error and enhance the algorithm’s pattern recognition capabilities by changing parameters. In unsupervised learning, updates aim to match an input. a predicted value based on the data shown. Due to their adaptability for pattern identification issues, decision trees (DT), artificial neural networks (ANNs), closest neighbour (NN), support vector machine (SVM), and naive bayes (NB) are the five most used algorithms in nuclear and radiological research applications. Fuzzy logic and evolutionary algorithms (EA) are also discussed since they have been used in some of the literature to solve nuclear and radiological-related problems as standalone algorithms or in conjunction with neural networks (i.e., neuro-fuzzy or neuro-evolutionary) [4, 5].

Multi-layered ANNs have outperformed other alternative machine learning methods (such as SVM) in the new millennium when data is abundant because they have improved representation learning via numerous hidden layers and improved optimization algorithms that facilitate training. According to the universal approximation theorem, there exists a neural network with at least one hidden layer and a finite number of units that can estimate any function at any desired degree of precision.This is the case for ANNs. Additionally, the use of graphical processing units (GPUs), which are excellent at performing quick matrix and vector multiplications necessary not just for image processing but also for other tasks, led to a breakthrough in training speed [6-8].

According to the specs, GPU hardware showed a speed gain of 20 or more over central processing units (Oh and Jung, 2004), as well as higher computational scalability. (CPUs). In machine learning applications including object recognition, speech recognition, adversarial games, and controls, deep learning (DL) models have quickly advanced to become the cutting-edge technology. Convolutional neural networks and long short-term memory are the two most widely used deep learning structures for sequential information with time dependencies and object detection in photos, respectively. Although their applications in nuclear sciences have been very limited and their proper tuning requires advanced knowledge, some instances include using video to identify steel flaws underwater [9].

Conclusion

This paper provides an overview of some machine learning

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techniques used in nuclear science and related engineering. The goal of the authors is to enable and hasten the scientific and technological outcomes of learning-based techniques by assisting researchers in understanding the advantages of new technologies as applied to the nuclear science domain. Furthermore, it is essential that the development and application of machine learning algorithms have as their main objective the provision of quick estimation for better decision-making by users (humans in the loop), as well as the assurance of the models' interpretability and reproducibility. Last but not least, it is recommended to leverage contemporary research accelerators that enable active (virtual) debate and partnerships in order to speed up invention. [10].

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Potential Conflict of Interest

No conflict or competing interests in the publication of this paper.

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