https://rijournals.com/biological-and-applied-science/

RESEARCH INVENTION JOURNAL OF BIOLOGICAL AND APPLIED SCIENCES 3(2):32-35, 2024

Online ISSN: 1115-6171

Print ISSN: 1597-2879

The Role of Artificial Intelligence in Predictive Maintenance of Industrial Equipment

Nzeyimana Eric Titus

Faculty of Engineering Kampala International University Uganda

ABSTRACT

Predictive maintenance is becoming increasingly vital in industrial settings due to the need to reduce downtime, optimize operational efficiency, and manage the wear and tear of machinery. Artificial intelligence (AI) has emerged as a crucial technology in enhancing predictive maintenance by enabling more accurate forecasting of equipment failures and optimizing maintenance schedules. This paper explores the role of AI in predictive maintenance, focusing on machine learning and deep learning algorithms, their implementation in industrial environments, and real-world case studies demonstrating their effectiveness. The integration of AI-driven predictive maintenance systems significantly reduces costs, extends equipment lifespan, and ensures uninterrupted production processes.

Keywords: Artificial Intelligence (AI), Predictive Maintenance, Machine Learning, Deep Learning, Industrial Equipment.

INTRODUCTION

Artificial intelligence plays a more and more important role in the predictive maintenance of industrial equipment. It is difficult to forecast the failure of the equipment, so as to reduce the downtime and energy consumption due to the unpredictability of the operation duration of the equipment, while still remaining a challenging task for the engineer. We do not think that this is necessary since the failure modes can be obtained by the FMEA. With the predefined failure modes, it is possible to forecast the failure time in advance. Accidental operation of the equipment is able to be forecasted in advance, then the maintenance can be very simple, including the detection of the failure time and scheduling the maintenance of the equipment. The presented concept can be extended to the predictive maintenance and fault prediction area [1]. There is also another reason for us to think that the defect cannot be monitored in an efficient way, mainly for the rotating equipment, such as the motor, pump, and blower, et al. The local area of the failing equipment is too small to find the failure of the components effectively. Quite a few faults occur inside the equipment before reaching the outer surface of the equipment. It means that the defect can grow for a very long time before reaching the outer surface, accordingly. Many machines operate at high speed and are installed in a place which is difficult to reach. It takes a fair amount of finance to refurbish one piece of the equipment, so on-time maintenance which can extend the mean time before failure is rather profitable [2].

FUNDAMENTALS OF PREDICTIVE MAINTENANCE

In a number of industries and technical systems with distributed and overlapping functions, a break can cause a chain of breakdowns that can generate significant losses in terms of both time and finances. Therefore, predictive maintenance is an important discipline. Predictive maintenance is the practice of defining the next time to replace industrial equipment to avoid serious problems, large repairs, and unexpected breakdowns. Taking inspiration from predictive maintenance, faults occurring from the stochastic distribution of the machine movements and loads can be mostly periods of contagion followed by a period of latency. Such faults can be divided according to the factor responsible for them: physical state (i.e., wear), operation, and human factors. The strategy for carrying out maintenance of such assets is typically basic preventive maintenance, such as replacement of the machine once worn, lubrication with the chosen frequency at the time of the start-up, and inspection at the beginning of the stop or processing [3].

One solution to the limitations of the classical approaches is predictive maintenance. The basic principle of predictive maintenance (PdM) consists of "examining the state of the equipment on a regular basis in terms of performance capable of measuring the performance after a characteristic parameter, such as noise, temperature, vibration, and angle wear." The most common organizations applicable to PdM techniques are: International Organization for Standardization International Maintenance Institute (ISO/TC154); The reliability and maintenance research covering about 50 authors; Any other technical associations such as SEM, IEEE, CIGRE, VDE, and DIN. Alternatively, in the context of machines, particularly on route-based technologies, provide recommendations for the application of PM technologies that are divided into two main steps: technologies corresponding to route technologies will reveal symptoms of failure, damage, or approaching both of them; and the technologies of complimentary RMBD vibration analysis, lubrication, and maintenance will be performed to establish the correct equipment condition concerning residual months [4].

ARTIFICIAL INTELLIGENCE TECHNIQUES FOR PREDICTIVE MAINTENANCE

Predictive maintenance (PdM) is essential in managing processes and industrial equipment to optimize productivity. Artificial intelligence plays a key role in enhancing this process by sensing equipment failures and providing timely alerts. It upgrades traditional maintenance systems into smarter ones, saving costs and improving systems intelligence. The United States Department of Defense defines predictive maintenance as basing maintenance needs on actual equipment condition rather than a preset schedule [5]. Machine learning methods or algorithms are substantially significant to advance the predictive maintenance process. These have the capacity to automatically learn from and make predictions or decisions based on data. An essential quality of machine learning techniques is their ability to complete the tasks autonomously in order to improve the experience. These abilities are divided into three types: unsupervised learning, supervised learning, and reinforcement learning. Reinforcement learning is not suitable for the topic of predictive maintenance. Supervised learning can be employed for fault detection. In the field of predictive maintenance, anomaly detection has been regarded as a suitable technique capable of utilizing the label for normal behavior only. Deep learning models have been proposed to extract features and utilize them for further classification. These techniques have been very significant in the development of machinery fault diagnostics [1].

MACHINE LEARNING ALGORITHMS

In predictive maintenance, machine learning algorithms are used to train from available data, typically time series (sensor) data, to learn model parameters for representing the operation behavior of the process or system. The model parameters are then used at runtime to continuously compare the actual performance against the learned operational behavior, which allows the identification of the deviation from the normal, and as such, the generation of alerts or predictions associated with potential failures or degradation [6]. The main approaches for predictive maintenance of industrial equipment are supervised and unsupervised learning. Supervised learning involves extracting features from training data and interpreting them to anticipate faults/defects. Unsupervised learning uses self-learning or anomaly detection to identify deviations from normal operation [7]. Presently, due to the increase in the volume and variety of big data, most predictive maintenance systems are based on machine learning algorithms. From reinforcement learning, collaborative filtering, bagging, boosting to support vector machine, these algorithms demonstrated improved prediction efficiency compared to purely analytical techniques, especially in relation to non-stationary systems. In addition to being able to identify a defective system, the machine learning algorithms also provide support in determining which out of many components are likely to have the maximum effect on the end product, allowing for a more effective response against failure. This aspect makes the machine learning algorithms currently the most efficient and widely-used solution in predictive maintenance of industrial equipment [8].

DEEP LEARNING MODELS

Deep learning is a subtype of machine learning used in predictive maintenance. It is best for complex relationships and large operations. Deep learning networks can be supervised, unsupervised, or reinforcement models. They include feedforward, recurrent, and attention models [9]. In most cases, it is plausible to classify the objectives using deep learning models that are trained on input-to-target data records. Recurrent networks are used for modeling sequential or time-series data, e.g., internal or external signals from big machinery including smart sensors. Hebbian learning algorithms are utilized with unsupervised and reinforcement models to cluster input records into similar classes. Sometimes it is plausible to use deep learning models based on a similar supervised paradigm even when there is no clear single-target parameter to diagnose. For example, in a car, there can be many operations within normal limits, and their confluence can be classified using any supervised learning concept as the class "healthy" to detect a novel problem. For example, internal ambient cassette temperature + global humidity + paper texture + feed V-belt speed + dye fluid flow + read-head rotation >< Error flag on a particular cylinder is abnormal [10].

IMPLEMENTATION OF AI IN INDUSTRIAL SETTINGS

Given the challenges related to broken parts and out-of-schedule downtime, industries and enterprises are more and more interested in employing AI to cope with predictive maintenance and anomaly diagnostics on their equipment. AI technologies may create a range of opportunities in the on-site maintenance of equipment in various industrial settings, although the implementation of these technologies may seem to be challenging. To capitalize on opportunities and alleviate some of the challenges associated with such AI techniques in a practical industrial environment, a number of requirements have to be satisfied [1]. The practical adoption of AI in conjunction with intelligent maintenance strategies is known as cognitive maintenance, supporting the intelligence-maintenance concept to perform knowledge-driven maintenance operations. Using AI, tools and self-contained/chatbot-based maintenance assistants achieve such functions. Furthermore, AI has shown great efficacy in predictive analytics, such as preventive strategic diagnostics of different types of machining equipment in the manufacturing and processing industries, intelligent maintenance service design, and digital twin technology. In addition to these tools, an AI-support system pilots the assistant's action based on their expert analysis and judgment to optimize maintenance operations. These settings are then discussed more deeply. Currently exploited AI techniques and their applications for various predictive maintenance operations in industrial scenarios are also discussed in the following [11].

CASE STUDIES AND REAL-WORLD APPLICATIONS

While it is true that many academic papers have proposed various AI models for predictive maintenance, it is still not apparent how AI actually contributes to predictive maintenance in industry. By contrast, this section succinctly provides real-world case studies that demonstrate the successful implementation of AI models in industrial equipment maintenance [1]. In the "Everguard Project" case, a successful mechanism is described in detail, which combines a-priori information and AI-based statistical models to predict the time when helicopter engines have to be replaced. A total of 121 lamps were installed and carried for 6801 landings (flight time, FT). The algorithm determined the RULs for seventy-nine lamps, of which two burned down with no warning. In this field test, our algorithm showed promising results. The experiences of the managers of two units within Everguard's corporate settings can be summarized by the player captain, who stated: "When these RCM policies have to be adjusted and competitive vehicle replacements have to be predicted, there is less of a need for interval maintenance and more reasons to replace units based on condition rather than risk analysis. An income increase may be achieved since the traded vehicle is a least-cost option on where all vehicles in good mechanical condition are available even if there are only one or two vehicles which are not. The result is a more simplified maintenance strategy, easy to understand and knowledge transfer of when to replace vehicles can now be institutionalized as a set of business rules for rescheduling maintenance, vehicle replacement, and trading options" [12]. In FedCom, a successful algorithm using hybridly combining time, event, and chaotic prediction is proposed in the context of the Federal Aviation Administration's Rotorcraft Maintenance Program to monitor bearing health and lubricating systems [13].

CONCLUSION

The application of artificial intelligence in predictive maintenance is revolutionizing how industries approach equipment management. AI-powered tools offer superior fault detection, optimize maintenance schedules, and predict potential equipment failures with greater accuracy than traditional methods. By leveraging machine learning and deep learning models, industries can anticipate maintenance needs, reduce unplanned downtimes, and extend the operational life of their equipment. Real-world implementations have shown that AI not only improves efficiency but also provides substantial cost savings. As AI technologies continue to evolve, their integration into predictive maintenance will become increasingly essential for industries aiming to maintain a competitive edge in the era of Industry 4.0.

REFERENCES

1. Achouch M, Dimitrova M, Ziane K, Sattarpanah Karganroudi S, Dhouib R, Ibrahim H, Adda M. On predictive maintenance in industry 4.0: Overview, models, and challenges. Applied Sciences. 2022 Aug 12;12(16):8081. mdpi.com
2. Li X, Zhang W, Ding Q, Sun JQ. Intelligent rotating machinery fault diagnosis based on deep learning using data augmentation. Journal of Intelligent Manufacturing. 2020. [HTML]

3. Bouabdallaoui Y, Lafhaj Z, Yim P, Ducoulombier L, Bennadji B. Predictive maintenance in building facilities: A machine learning-based approach. Sensors. 2021 Feb 3;21(4):1044. mdpi.com
4. Tiddens W, Braaksma J, Tinga T. Exploring predictive maintenance applications in industry. Journal of quality in maintenance engineering. 2022 Feb 11;28(1):68-85. utwente.nl
5. Regnier E, Hudgens BJ. Condition-Based Maintenance Implementation and Potential in USMC Ground Transport. 2022. dtic.mil
6. Ayvaz S, Alpay K. Predictive maintenance system for production lines in manufacturing: A machine learning approach using IoT data in real-time. Expert Systems with Applications. 2021. [HTML]
7. Kumar P, Hati AS. Review on machine learning algorithm-based fault detection in induction motors. Archives of Computational Methods in Engineering. 2021. academia.edu
8. Çınar ZM, Abdussalam Nuhu A, Zeeshan Q, Korhan O, Asmael M, Safaei B. Machine learning in predictive maintenance towards sustainable smart manufacturing in industry 4.0. Sustainability. 2020 Oct 5;12(19):8211. mdpi.com
9. Indrakumari R, Poongodi T, Singh K. Introduction to deep learning. Advanced Deep Learning for Engineers and Scientists: A Practical Approach. 2021:1-22. [HTML]
10. Hu J, Wang X, Zhang Y, Zhang D, Zhang M, Xue J. Time series prediction method based on variant LSTM recurrent neural network. Neural Processing Letters. 2020 Oct; 52:1485-500. [HTML]
11. Javaid M, Haleem A, Singh RP, Suman R. Artificial intelligence applications for industry 4.0: A literature-based study. Journal of Industrial Integration and Management. 2022 Mar 21;7(01):83-111. [HTML]
12. Moon H. Constructing the Modern Warrior: The US Army and Gender. 2021. wm.edu
13. Cheng W, Wang Y, Peng Z, Ren X, Shuai Y, Zang S, Liu H, Cheng H, Wu J. High-efficiency chaotic time series prediction based on time convolution neural network. Chaos, Solitons & Fractals. 2021 Nov 1; 152:111304. [HTML]

CITE AS: Nzeyimana Eric Titus. (2024). The Role of Artificial Intelligence in Predictive Maintenance of Industrial Equipment. RESEARCH INVENTION JOURNAL OF BIOLOGICAL AND APPLIED SCIENCES 3(2):32-35.