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APPLICATION OF AI IN MAINTENANCE AND RELIABILITY MANAGEMENT

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Abstract
In today's world, Globalization and fast-growing economics force enterprises and governments to keep up with the times. Stakeholders are highly interested in reducing downtime, directly impacting profitability rates and customer satisfaction. Under that pressure, maintenance managers and other stakeholders should consider how to alter their current practices and make their systems more efficient and reliable. Many industrial organizations such as ExxonMobil, BP, Chevron, Equinor, Repsol, Total, and others have already invested in AI projects related to predictive analytics to increase reliability levels and optimize their supply chain operations (Tom Mostyn, 2019).

Keywords Reliability management, Application of AI, ExxonMobil, maintenance managers and other stakeholders.

INTRODUCTION

The rapid evolution of AI technologies such as machine learning, deep learning, the Internet of Things, blockchains, and robotics is revolutionizing the maintenance sector. This article will delve into how the implementation of artificial intelligence is fundamentally transforming traditional maintenance management principles. It will explore AI's potential benefits and the challenges it faces today. This article will focus on AI's most notable and effective applications in maintenance management, such as predictive analytics, live monitoring and data collection, operational transparency, and inventory management.

PREDICTIVE MAINTENANCE

It is a matter of common knowledge that traditional maintenance practices are based on two main vectors – preventive and reactive maintenance. Reactive maintenance includes situations when a malfunction occurs unexpectedly, leading to extensive downtimes of a particular equipment or, in the worst scenario, to complete shutdown of production operations. Meanwhile, preventive maintenance involves regular asset inspections by a schedule and specific service procedures, which often can be time-costly and inefficient. To make malfunctions more predictable, vast data should be gathered and analyzed thoroughly. However, processing and analysis of immense volumes of such data are challenging and time-consuming for human beings, and artificial intelligence is one of the best tools to reach the best results in predicting failures.

From a predictive maintenance perspective, AI algorithms can forecast malfunctions by leveraging historical data, sensor information, log records, staff feedback, etc. Machine learning technologies can identify deviations from standard patterns and inform maintenance teams before failure occurs by utilizing and analyzing vast amounts of data. Such valuable forecasts can lead to sustainable operations and significant cost savings. For example, the US Air Force, by leveraging Amazon

Web Services (AWS), could save around $8.4M by avoiding reactive maintenance activities within ten months of regular operations. Furthermore, using AI as a prediction tool helped the US Air Forces avoid unnecessary parts replacement by 18% during the same frame of time (1, Ann Claire Carnahan, 2021).

Prescriptive maintenance

Besides prediction capabilities, ML technologies can also use the input data for prescriptive purposes. Deep learning is another type of machine learning with higher analytical and self-learning abilities. Moreover, it can process even more complicated analyses in one piece of equipment and in a group of assets connected to AI processing machines (D. Shaidauf, E. Bowen, D. Williams, E.Schoenbrun, H. Diaby, 2023). Deep learning machines identify abnormalities in data that outweigh normal values and subsequently inform maintenance teams about it. By providing such information, AI enables maintenance management to identify equipment wear level and its remaining useful life. It also helps to plan operations by balancing equipment load and workforce arrangement.

Another advantage of prescriptive maintenance is the ability of ML, in collaboration with AI and the Internet of Things (IoT), to provide estimates and recommendations. By studying historical and real-time data, the ML can recommend required actions for specific equipment or adjustments even for the whole system. In this case, ML generates different models based on provided data and runs simulations multiple times until it receives the most precise outputs. Therefore, it can generate recommendations for maintenance teams, the latter can analyze the outcomes manually. Moreover, ML, run by AI, can identify the asset's remaining life by deep learning the operational patterns and current condition from the sensors of the equipment (Anwar et al., 2024). Besides, ML has the capability to optimize service operations by focusing on the most critical or vulnerable assets that need extra attention from maintenance crews.

IoT and real-time monitoring

In the modern technological world, various measuring equipment, whether mechanical or digital, has been used for many years for production operations control and analysis. Nevertheless, digital sensors bring many benefits today, such as precision, real-time monitoring and control, remoteness, automation, and eligibility for live analysis and data-driven model processing by ML and AI. The modern name of sensors or connectable measuring devices is the Internet of Things (IoT). IoT, in collaboration with ML and AI, provides opportunities to manage operations smoothly, avoid risks, and have precise forecasts on hand.

Having precise data about operational equipment is crucial for any industry, and IoT can significantly enhance information collection processes. Imagine an oil refinery plant where thousands of gauges and sensors measure and indicate different operational parameters used for production adjustment, decision-making, and risk management. So, a well-developed network of IoT connected to an ML processing machine can make that process times faster and provide deep analytical reports and forecasted scenarios.

Operations Transparency and Blockchain

Another valuable feature of artificial intelligence is blockchain technology, which was initially developed for cryptocurrency registration only. Nevertheless, today, blockchain is widely used in various industries, such as supply chain management, real estate, gaming, and healthcare. The key feature of blockchain technology is that it saves information on multiple servers and is protected from edition and deletion (Danny Pehar, 2024). Thereby, the information entered will remain on those servers forever. That feature can be leveraged in maintenance management for more transparent operations and to ensure historical data backup storage.

Using blockchain in maintenance can bring many benefits in terms of transparency. For instance, historical data saved on multiple servers can be used in different investigation or commissioning processes. Imagine when a critical failure occurs on a power plant, which leads to social or environmental consequences – long-term power and water outages or excessive pollution in

surrounding areas. In such situations, truthful data is key for investigators to identify root causes and mitigate such compliance in operations and maintenance practices. Therefore, blockchain technology has great potential to improve industries in terms of legal and environmental compliance.

Inventory management

Spare parts and consumables are among the significant issues in maintenance management, which require quality, transparency, and availability. Blockchain technologies can be utilized to track the origin of spare parts or consumables to ensure the quality of materials provided by suppliers. Of course, it will depend on how the blockchain system was designed and its options and access levels, but it is possible to track the origin up to the source of raw materials from which details were made. Maintenance managers can make informed decisions when choosing suppliers and contract issues.

Inventory control and management – a widespread problem of modern enterprises which not so easy to solve. Maintaining inventory levels involves a vast amount of data, and usually, it is challenging to predict the exact quantity of needed parts or consumables. AI and ML technologies can be more than helpful in this situation. As in the prediction and prescription sections, ML analyzes historical data and generates patterns for creating a virtual model on spare demand. Unlike traditional planning, during analysis, AI can also consider different occasions that occurred previously and affected the inventory. Therefore, a collaboration between AI and ML can significantly contribute to supply chain management upgrades, perform material planning, and provide quality confidence and transparency.

Challenges

Costs

Implementation of AI into the maintenance process varies and depends on the customer's personal requirements. Today, simple AI solutions would cost at least $400-500K for small projects and up to tens of millions of dollars for bigger ones (Jon Reilly, 2024). Despite high prices, big organizations and joint ventures do not hesitate to implement AI technologies into their operations, and Repsol petrochemical company is one of them. Repsol from previous projects of implementing AI as a predictive analytics tool has witnessed notable cost savings of around $200M annually from reducing reactive maintenance activities (Tom Mostyn, 2019). In this regard, Repsol is planning to expand the AI implementation program and is planning huge investments in the 2024-2027 Repsol Strategic Update (Repsol S.A., 2024).

Technological complexity

Implementing AI in maintenance processes and hardware systems would bring various difficulties in addition to high prices (Jon Reilly, 2024). The logic is the same as with prices: the higher the requirements, the more complex the system will be. The challenges can vary from hardware and software to administrative or regulative restrictions. Moreover, designing and implementing AI projects in maintenance processes requires the application of knowledge and expertise from both sides—the client and the provider of AI services. Just imagine a situation where a provider of AI services cannot completely understand the operations philosophy of his client due to a lack of expertise in that field. Such a relationship is not effective and can barely bring good results.

Another issue is the digitalization of the whole process. As was described before, AI and ML technologies require a vast amount of high-quality data, and the best way to its collection is to completely digitalize the system (Christian Langer et al., 2024). That measure would give a raw of benefits such as live monitoring, data recording, and storage. However, not every system can be wholly digitalized due to various environmental obstacles. For instance, it is a challenging problem to install some kind of sensors in zones with high levels of radiation, temperature, pressure, or vibration.

Personnel education

As with any innovation, AI and ML bring difficulties for personnel using new systems and software that require some expertise. In that regard, companies

should consider that fact before implementing such emerging technologies. Stakeholders and managers should consider arranging special courses and practical exercises for laborers who will be in touch with AI systems. Today, there are plenty of ways to educate personnel on AI principles, such as various online platforms, workshops, simulators, or continuous education programs.

Data volumes and quality

Despite ML's valuable benefits through its analytical capabilities, it also needs a vast amount of high-quality data to produce more precise outcomes. The colossal information hub enables ML to scrutinize the data to understand long-term patterns and variability. The more information you input, the more complex the system is (Hrvoje Smolic, 2024). However, ML would struggle to identify precise and accurate models in situations without huge volumes of high-quality information.

Besides quantitative data requirements, ML also needs systematic data entry, one of the most challenging processes in applying ML technologies to business operations. If the data collection process is fully automated and digitalized, it will allow the system to read and analyze the inputs and generate accurate patterns steadily. However, semi-automated or manual data collection systems require strict rules and procedures in the data collection process, particularly for personnel who record and input the data into the ML processing machine. Inaccurate or incorrect inputs will lead to erroneous model generation and, consequently, to inaccurate forecasts.

CONCLUSION

To conclude, AI and ML technologies have become the new norm today, and many organizations tend to apply those technologies to their business operations. Applying AI in combination with ML and IoT in maintenance management can significantly enhance the reliability levels of any enterprise. Implementing such emerging technologies can lead enterprises to sustainable, transparent, and safe operations, which in turn can strengthen the company's name and reputation on the market. According to Deloitte's research, predictive maintenance can substantially increase the main KPIs – save costs in operations by up to 10%, increase equipment uptime by up to 20%, reduce overall maintenance costs to 10%, and significantly cut maintenance planning time by almost twice (Olaf Peter Schleicher et al, 2017)

Another considerable benefit is cost savings through failure and downtime reduction. British Petroleum (BP) can be considered a perfect example, having saved around $7B during the 2014- 17 period (Andrew Carr, 2017). So, potentially costly investments can be returned pretty fast, and the most value you gain is reliability and customer satisfaction. Of course, any investment in such technology should be preliminary analyzed by stakeholders and reviewed by financial and technical experts.

In general, AI has been conquering the industrial sector for the last decade and should be considered as one of the key vectors in maintenance management development. Despite the variety of challenges, AI with ML technology has a bright future that can lead to sustainable supply chains and environmental and operational safety. Stakeholders, top managers, and professionals of different industries should now focus on the capabilities of emerging technologies such as AI and ML and consider their implementation into their operations because those technologies will remarkably change the industrial world in the near future.

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