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# Revolutionizing Diagnostics, Prognostics and Health Management for Complex Mechanical Structures Through AI: Opinion

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Artificial Intelligence (AI) is revolutionizing intelligent diagnosis and health management of complex mechanical systems, especially for low accessible equipment such as aerospace systems, offshore structures, underground/subsea machinery. The demand for high reliability and safety accelerated the development and application of AI tools and which has become an essential support for enhancing the operational efficiency and safety of recent-developed systems. AI methods are especially good at handling big data situations by extracting useful and targeted information from real-time data reported by sensors (numerical data) and maintenance records (textual data), producing evidence for fault detection, diagnosis, prognosis, and remaining useful life predictions, which are able to be extended to reliability, availability and operation and maintenance investigations of systems already mentioned above [1]. This intelligent health assessment capability empowers engineers to efficiently identify potential issues and implement preventive measures before failures/events or a minor situation turn out to severe consequences [2].

AI derives deeper insights from both monitoring and historical data, significantly alleviating the manual workload associated with fault diagnosis and improving the precision of complex problem-solving [3]. Generative AI effectively addresses challenges posed by limited historical fault data, enabling it to tackle increasingly intricate diagnostic tasks. However, the reliability and quality of (big) data play a vital role in fault diagnosis, which call for comprehensive integration of AI with the physical characteristics and behaviors exhibited by complex mechanical structures when health issues arise, facilitating the development of physically interpretable fault diagnosis methods.

Deep learning techniques uncover underlying patterns associated with equipment lifespan, thereby establishing effective health indicators. These indicators are crucial foundations for remaining useful life (RUL) prediction. Through monitoring health indicators, AI dynamically adjusts lifespan predictions, swiftly accounting for the impacts of operating conditions, environmental changes, and potential faults. This capability enhances the timeliness and accuracy of lifespan predictions. Furthermore, by analyzing variations in health indicators, AI provides assessments of structural reliability under varying operational conditions. Such assessments assist engineers in timely identification of potential structural issues. However, constructing effective health indicators and conducting life predictions still face challenges, including data quality, model selection, and the complexities of external environments. Therefore, the combination of AI with physical models to develop interpretable lifespan prediction methods enhances reliability of predictions and offers engineers with deeper insights toward more informed decisions.

Additionally, AI-driven health management seamlessly integrates multiple data sources through intelligent algorithms, enabling comprehensive monitoring and analysis of equipment status. This holistic approach aids in identifying equipment performance across various environmental conditions, thereby facilitating more flexible operations and management. Although challenges related to data security and privacy protection may arise, the application of AI undoubtedly presents unprecedented opportunities for the intelligent health management of complex mechanical structures. Looking ahead, AI is well-positioned to continue driving innovations in these fields, contributing to the development of safer, more efficient, and sustainable mechanical systems.

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