Advancing PHM with XAI: A Comprehensive Review and Application in Constructing Health Indicators for Multi-Component Systems

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Résumé

Prognostics and Health Management (PHM) plays a crucial role in industrial applications, enabling accurate predictions and insights into system health to prevent equipment failures and optimize maintenance strategies. The integration of data-driven Artificial Intelligence (AI) methods has significantly amplified PHM's capabilities, empowering precise predictions and comprehensive insights into system health. However, the black-box nature of these models raises concerns about their interpretability and trustworthiness.
In this light, we delve into the crucial role of Explainable Artificial Intelligence (XAI) in the realm of PHM. Our initial contribution is a comprehensive review of XAI within the PHM domain, where we not only explore existing methodologies but also provide clarity on the complex terminologies associated with XAI. This effort is complemented by the introduction of a comprehensive taxonomy for XAI in PHM, which serves as a guide for understanding and applying these methodologies in practical scenarios.
The paper's primary contribution lies in demonstrating the application of XAI in PHM through a detailed case study. Here, we focus on the development of a robust Health Indicator (HI) for systems with multiple interacting components. The design of this HI takes into account the mutual interactions among components and its robustness in different operational environments. To investigate the performance of this explainable HI, we employ the Tennessee Eastman process dataset. This case study showcases how XAI methodologies can be utilized to construct and enhance the interpretability of the HI, focusing on its adaptability to different mission profiles and the intricate interplay between system components. The integration of XAI techniques not only improves the predictive accuracy of the HI but also unravels its decision-making processes, establishing a transparent and interpretable framework for informed decision-making. Our findings demonstrate that the proposed approach, validated through the Tennessee Eastman process, advances the understanding of XAI methodologies within PHM and pioneers a new trajectory toward creating transparent, interpretable AI-driven systems in industrial applications.

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