Editorial for IJPHM Special Issue on PHM Asia Pacific Conference 2023

Prognostics and system health management (PHM) remain crucial for maintaining various industrial systems' reliability, safety, and efficiency. However, there remain gaps and challenges that need to be addressed. The special issue compiles 12 extended papers from the 2023 PHM Asia Pacific Conference, showcasing both the extensive research and a wide range of applications. It showcases research findings in autonomous system monitoring, fault detection, anomaly detection, and predictive maintenance. A common theme across the papers is the balance between computational efficiency, explainability, and real-world applicability. While the research presented here is highly innovative, it also highlights the need for PHM systems that are not only robust and scalable but also transparent and easily interpretable for end-users.

Autonomous system diagnostics:

The first set of papers addresses a critical area of development – autonomy. The paper *"Statistical Analysis and Runtime Monitoring for an AI-based Autonomous Centerline Tracking System"* extends the SYS-AI framework to improve safety assurance in AI-driven aerospace systems. This work is timely and important, given the rising integration of AI in high-risk environments. The authors propose a valuable combination of statistical analysis and runtime monitoring across diverse operational environments. Similarly, the paper *"Framework for Data-Driven Fault Diagnosis of Numerical Spacecraft Propulsion Systems"* tackles the growing complexity of space missions, where communication delays with Earth necessitate autonomous fault diagnosis. The novel framework introduced in this research is an important contribution to PHM, particularly for deep-space missions. Sequential Forward Selection (SFS) for optimized sensor placement and feature selection is a clever approach to managing resource constraints.

The paper *"Efficient Differential Diagnosis using Cost-aware Active Testing"* introduces a methodology for systematically generating diagnostic models for complex systems, covering all types of diagnostic actions. It supports decision-making based on counterfactual reasoning to minimize the overall cost of diagnosis. Successfully applied to diagnosing cyber-physical systems in high-tech industries, this method also shows promise for computing intervention actions in autonomous robots.

These articles highlight the real-world limitations with computational power required for onboard spacecraft diagnostics. Efforts are therefore being focused on refining the balance between diagnostic accuracy and computational efficiency, particularly under operational constraints.

Explainability and anomaly detection in safety-critical systems:

As AI becomes increasingly embedded in safety-critical systems, ensuring the explainability of these systems is crucial for their adoption and operational safety. The paper *"Towards Explainable Anomaly Detection in Safety-Critical Systems"* makes an important contribution by proposing a novel methodology that combines Functional Resonance Analysis Method (FRAM) with machine learning-based anomaly detection. The authors effectively demonstrate the need for clear and actionable explanations, particularly in high-stakes environments such as the International Space Station. While these methods offer some practicality, the authors have cautioned against scalability and applicability to other domains beyond aerospace.

Additionally, the paper *"A Novel Approach using Transformer Neural Networks for Reconstruction and Residual Analysis"* introduces an unsupervised anomaly detection technique for marine diesel engines. Utilizing a Transformer Neural Network-based autoencoder (TAE) and residual analysis, the approach captures temporal dependencies within time-series data without the need for labeled failure data. The paper presents a comparative analysis of various Transformer neural network architectures and other neural networks, showing that the proposed method can accurately detect anomalies in marine diesel engines, which can prevent costly downtime and severe accidents.

Industrial and civil infrastructure:

A recurring challenge in PHM is the need for efficient, scalable solutions that can be applied to large-scale industrial and civil infrastructure systems. The paper *"Anomaly Sign Detection for Automatic Ticket Gates by the Histogram Limitation Method"* introduces a lightweight, cost-effective method for detecting early-stage anomalies in urban transportation systems. While the Histogram Limitation Method (HLM) shows promise, its reliance on simplified statistical methods may limit its applicability in more complex systems, where machine learning techniques may be necessary.

In the field of civil engineering, the paper *"Automatic Detection of Concrete Surface Defects Using Pre-Trained CNN and Laser Ultrasonic Visualization Testing"* offers an innovative approach to automating defect detection in concrete structures. The use of pre-trained convolutional neural networks (CNNs) represents a significant advancement in non-destructive testing. However, scaling and interpreting these methods for larger structures remains a challenge.

Energy systems:

The energy sector continues to be a fertile ground for PHM innovation, particularly in fault detection and predictive maintenance. The paper *"Enhanced Method for Localization of Partial Discharges in Oil-Filled Transformers Using Acoustic Emission Signals"* delves into an essential aspect of power grid reliability. The authors propose a robust method for early fault detection using acoustic emission (AE) technology, demonstrating its effectiveness in reducing downtime and improving transformer maintenance. The complex nature of AE data interpretation remains a challenge, requiring future work to focus on improving the usability of this technology for field engineers.

Another paper, *"Real-Time Detection of Internal Short Circuits in Lithium-Ion Batteries using an Extended Kalman Filter,"* addresses the critical issue of early detection of short circuits in lithium-ion batteries, particularly in electric vehicles. The innovative technique combines voltage measurements with surface temperature observations to estimate internal ISC states in real-time, demonstrating the potential to prevent thermal runaway and battery fires efficiently.

Similarly, *"A New Approach to Multivariate Statistical Process Control and its Application to Wastewater Treatment Process Monitoring"* showcases the adaptability of PHM in environmental management. This paper successfully adapts Multivariate Statistical Process Control (MSPC) to the wastewater treatment process, providing an accessible user interface for operators. These papers demonstrate that even if the user interface simplifies real-time monitoring, the diagnostic model still relies heavily on data quality and availability. This can vary significantly in real-world applications and more research will be needed to ensure the robustness of these methods in different environmental conditions and data environments.

Rotating machinery:

The paper *"Observation and Prediction of Instability due to RD Fluid Force in Rotating Machinery by Operational Modal Analysis"* addresses the rising concern of shaft vibration in rotating machinery. By applying operational modal analysis (OMA) methods, the study investigates the destabilization caused by rotodynamic (RD) fluid forces, a critical factor for ensuring machinery stability and safety. The validation of the proposed method through experimental data demonstrates its potential for improving vibration analysis technology in both the design and operational phases of rotating machinery.

Aircraft health management systems:

Finally, the paper *"An Effectiveness Evaluation Method Using System of Systems Architecture Description of Aircraft Health Management in Aircraft Maintenance Program"* offers a system modeling method for aircraft maintenance based on condition-based maintenance using aircraft health management. By incorporating a system-of-systems architecture, this methodology enhances the aircraft maintenance program, considering uncertainties related to airline operations and aircraft systems. The results demonstrate the effectiveness of this approach through an application on a tire pressure monitoring system, laying the groundwork for future improvements in aircraft health management.

This special issue touches on practical PHM topics, with key insights into the challenges of scaling, explainability, and real-world application, highlighting several areas that require further attention. First, the trade-off between computational efficiency and diagnostic accuracy is a recurring theme. Many of the proposed methods—though effective—are computationally intensive, limiting their scalability in resource-constrained environments like space or civil infrastructure. Second, while the importance of explainability is emphasized across multiple papers, the actual implementation of transparent, user-friendly diagnostic tools remains a work in progress. Finally, more comprehensive real-world validation is necessary to demonstrate the applicability of these methods across diverse operational contexts.

We would like to sincerely thank the authors, reviewers and journal editorial team for their hard work and dedication in making this special issue possible. We hope this collection serves as a valuable resource for researchers and practitioners in the PHM community.

Sincerely,
Takehisa Yairi, Samir Khan and Seiji Tsutsumi
Guest Editors
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