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Digital Twins for Data-driven Reliability Assessment of Cyber-Physical Production Systems

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In recent years, there has been a significant increase in the deployment of cyber-physical production systems (CPPS) across various industries. CPPS consist of interconnected devices and systems that combine physical and digital elements to enhance the efficiency, productivity, and reliability of manufacturing processes [1]. However, with the proliferation of these complex systems, there is a growing need for effective and efficient methods to assess their reliability and performance.

CPPS have introduced new challenges for traditional, expert-based reliability assessment of manufacturing systems. Firstly, reliability assessment is a time-consuming and labor-intensive process that requires significant resources to collect and analyze data manually. Secondly, expert-based assessments are prone to human errors and biases, as they rely on the individual expertise and experience of analysts. This can lead to inconsistent results and misinterpretation of data, which can have serious consequences for the reliability and safety of the manufacturing system. Finally, traditional methods may not be able to capture the dynamic behavior of CPPS, which typically evolve and change their topology and configuration throughout their lifetime [2,3].

One promising solution to these challenges is the use of digital twins (DTs) for data-driven reliability assessment (DDRA) of CPPS. DTs are virtual representations of physical assets or systems that can be used to simulate and analyze their behaviors and performance. Digital twins provide a means to collect and analyze real-time data from physical systems, enabling engineers and operators to identify potential issues and optimize reliability [4]. By leveraging DTs, DDRA can generate accurate reliability models rapidly and reduces the need for subject matter experts. In addition, DDRA can provide manufacturers with better insight and understanding of the root causes of failures. Finally, DDRA can assist decision makers in maintenance planning, machine purchasing, or plant layout configuration, contributing to more efficient resource allocation [2].

We provide a comprehensive overview of DDRA for CPPS, exploring key concepts, methods, and tools involved. We specifically focus on the data requirements to automate reliability modeling in a manufacturing context and highlight the formalisms that are most suitable for DDRA. Additionally, we present recent research on the validation of data-driven reliability models, providing insights into the accuracy and robustness of results achieved by using DDRA. To demonstrate the real-world benefits of DDRA, we showcase several case studies conducted in collaboration with manufacturers that highlight how this approach can be used to enhance the reliability and performance of CPPS.

References

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