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Big data analytics solutions to improve nuclear power plant efficiency: Online monitoring, visualization, prognosis, and maintenance decision making

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ABSTRACT:
The overarching goal of this project is to significantly advance the ability to assess equipment condition and predict the remaining useful life (RUL) to support optimal maintenance decision making in nuclear power plants. This will be accomplished by establishing a modern set of data-driven modeling, online monitoring, visualization, prognosis, and operation decision-making methodologies to address the significant opportunities and challenges arising from the emerging data-rich environment in nuclear plants. The rapid advances in sensor technology and communication infrastructure are enabling an unprecedented opportunity for data collection, making real-time analytics and decision making possible. The collected data are heterogeneous and contain massive amounts of information, and include historical records of critical events from operator maintenance logs and condition reports, as well as condition monitoring (CM) sensor signals that continuously measure different characteristics of equipment performance, such as temperature, pressure, power, vibration, and flow. However, we are currently lacking Big Data analytics methodologies that can fully leverage the available data to accurately assess equipment condition and predict RUL. Such approaches could greatly improve maintenance decision making in the nuclear plant. Our project aims to precisely address this critical research need. Specifically, a logical path will be pursued, including: (1) Natural Language Processing (NLP) algorithms that capture the critical log events recorded by operators and historical CM signals collected from plant equipment; (2) effective machine learning (ML) algorithms that quickly detect and identify abnormal events based on the Big Data streams of CM signals in real time; (3) a novel data fusion model for visualizing degradation status (DS) evolution by fusing multiple CM signals; (4) a real-time prognostic algorithm that allows continuous updates of RUL predictions based on online measurements from equipment; (5) a plant-level predictive maintenance strategy that aims to reduce maintenance cost and improve plant efficiency; and (6) testing and validation of our methods using both simulation and real-world data provided from our industrial collaborator.

The potential impact of our project is significant and transformative and will deliver important advances in productivity with reduced unscheduled downtime and improved equipment performance. It will also enhance equipment safety and utilization, lower maintenance cost, improve operation readiness and efficiency, and ultimately help the U.S. gain a significant competitive advantage in nuclear power. Our team has the necessary collective expertise to execute these tasks—involving industrial data analytics and fusion, statistics and ML, design and operation of nuclear power plants, and industrial practice, as well as experience in leading breakthrough research initiatives. This project features a close collaboration with an industrial company, which has agreed to collaborate closely on this project to enable the testing, validation, and demonstration of our research outcomes using real-world equipment data and use-cases, and to facilitate the transfer of our innovations to practice.