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Predictive Maintenance: Machine Condition Real-Time Monitoring and Failure Prediction

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Abstract : Predictive maintenance is a technique to predict when an in-service machine will fail so that maintenance can be planned in advance. Analytics-driven predictive maintenance is gaining increasing attention in many industries such as manufacturing, utilities, aerospace, etc., along with the emerging demand of Internet of Things (IoT) applications and the maturity of technologies that support Big Data storage and processing. This study aims to build an end-to-end analytics solution that includes both real-time machine condition monitoring and machine learning based predictive analytics capabilities. The goal is to showcase a general predictive maintenance solution architecture, which suggests how the data generated from field machines can be collected, transmitted, stored, and analyzed. We use a publicly available aircraft engine run-to-failure dataset to illustrate the streaming analytics component and the batch failure prediction component. We outline the contributions of this study from four aspects. First, we compare the predictive maintenance problems from the view of the traditional reliability centered maintenance field, and from the view of the IoT applications. When evolving to the IoT era, predictive maintenance has shifted its focus from ensuring reliable machine operations to improve production/maintenance efficiency via any maintenance related tasks. It covers a variety of topics, including but not limited to: failure prediction, fault forecasting, failure detection and diagnosis, and recommendation of maintenance actions after failure. Second, we review the state-of-art technologies that enable a machine/device to transmit data all the way through the Cloud for storage and advanced analytics. These technologies vary drastically mainly based on the power source and functionality of the devices. For example, a consumer machine such as an elevator uses completely different data transmission protocols comparing to the sensor units in an environmental sensor network. The former may transfer data into the Cloud via WiFi directly. The latter usually uses radio communication inherent the network, and the data is stored in a staging data node before it can be transmitted into the Cloud when necessary. Third, we illustrate show to formulate a machine learning problem to predict machine fault/failures. By showing a step-by-step process of data labeling, feature engineering, model construction and evaluation, we share following experiences: (1) what are the specific data quality issues that have crucial impact on predictive maintenance use cases; (2) how to train and evaluate a model when training data contains inter-dependent records. Four, we review the tools available to build such a data pipeline that digests the data and produce insights. We show the tools we use including data injection, streaming data processing, machine learning model training, and the tool that coordinates/schedules different jobs. In addition, we show the visualization tool that creates rich data visualizations for both real-time insights and prediction results. To conclude, there are two key takeaways from this study. (1) It summarizes the landscape and challenges of predictive maintenance applications. (2) It takes an example in aerospace with publicly available data to illustrate each component in the proposed data pipeline and showcases how the solution can be deployed as a live demo.

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