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A Semi-Supervised Framework for Optimisation-Based Label Inference in RUL Prediction

Industrial systems generate large volumes of operational data, enabling predictive maintenance strategies to reduce unplanned downtime and costs. Over the past decade, machine learning (ML) models have been widely used for predicting equipment degradation. However, their effectiveness is constrained by the scarcity of high-quality labels, as industrial datasets remain largely unlabelled. Existing labelling approaches typically rely on expert domain knowledge or simplified degradation assumptions, which can introduce bias and limit generalisability.

This work proposes a novel semi-supervised framework for inferring key performance indicators, including Remaining Useful Life (RUL), from limited labelled data. The approach formulates label estimation as an optimisation problem, where candidate labels are iteratively updated to minimise prediction error. Long Short-Term Memory (LSTM) neural networks are constructed within each iteration to evaluate solution quality and guide the optimisation process, enabling progressive refinement of inferred labels while improving predictive accuracy.

The framework is evaluated on two established predictive maintenance datasets. Initial results indicate that it can effectively infer the RUL for large amounts of previously unlabelled data and achieves high predictive accuracy on unseen batches. Furthermore, by extracting additional process information from the newly labelled batch data, the framework expands the effective training dataset and enables continuous refinement of the LSTM networks. This allows them to learn a more comprehensive representation of system behaviour and supports the development of more robust and transferable predictive maintenance models.

Special/ Invited session

Classification

Mainly methodology

Keywords

Semi-Supervised Learning, Label Inference, Predictive Maintenance

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Track Classification: Time Series, Forecasting and Dynamic Systems