Physics-Based Recurrent Neural Network for Failure Prognostics of Rolling Element Bearings

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Failure prognostics of rolling element bearings is essential for enabling predictive maintenance of industrial and agricultural machinery. Existing techniques for bearing failure prognostics are mostly data-driven and the performance of such techniques is limited by the size and quality of the training dataset. By incorporating the physical knowledge about bearing failure mechanisms, we develop a physics-based recurrent neural network for failure prognostics of rolling element bearings. Our proposed approach has three unique features: (1) a new data augmentation technique is proposed to improve the accuracy and robustness of remaining useful life (RUL) prediction in cases where a deep learning model only has access to a small amount of training data. The proposed technique artificially increases the size of the training data by randomly interpolating the run-to-failure trajectories of each training unit. (2) The physical knowledge about bearing faults is incorporated during the extraction of fault-related features and construction of a health index (HI). The fault-related features are extracted by analyzing the vibration amplitudes in a sub-band frequency domain around each of the fault characteristic frequencies. A similarity-based approach is developed to track the fault propagation and consequently constructing the HI of a bearing unit. An auto-encoder technique is also applied to maximize the extraction of prognostic information from sensor signals. (3) A temporal filtering mechanism is built in a recurrent neural network architecture, namely long short-term memory (LSTM), to improve the robustness of RUL prediction. Our approach is tested on the publicly available XJTU-SY bearing dataset comprising of run-to-failure experimental data of rolling element bearings. Preliminary results demonstrate the effectiveness of the proposed approach in improving the accuracy and robustness of RUL prediction.