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ARTICLE

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MULTI-SCALE RECURRENCE QUANTIFICATION ANALYSIS OF TIME SERIES FOR BEARING HEALTH MONITORING

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Integrated Vehicle Health Management (IVHM) systems play a crucial role in ensuring the safety, reliability, and efficiency of modern aircraft by monitoring critical components such as bearings, which are integral to engines, landing gear, and control surfaces. This study presents a novel method combining Discrete Wavelet Transform (DWT) and Recurrence Plots for bearing health monitoring. DWT is used to decompose signals into frequency bands via high-pass and low-pass filters, and the resulting signals are analyzed with Recurrence Quantification Analysis (RQA) to extract 91 features. These features are utilized for fault classification using C-Support Vector Machine (CSVM), Quadratic Support Vector Machine (QSVM), and Linear Discriminant Analysis (LDA). Initially, employing all 91 features resulted in perfect training accuracy (100%) across all classifiers. Feature selection using error plots identified two optimal features, yielding training accuracies between 82.7% and 84.3% and testing accuracies from 80.2% to 86.4%. Further analysis demonstrated that the QSVM achieved the highest testing accuracy among the selected features, while the CSVM consistently delivered 100% testing accuracy. With feature selection algorithms, LDA achieved a training accuracy of 98.4% and a testing accuracy of 98.8%, whereas QSVM and Cubic SVM both attained 99.7% training accuracy, with QSVM reaching 98.8% testing accuracy and Cubic SVM achieving perfect 100% testing accuracy. These results highlight the effectiveness of integrating wavelet-based feature extraction with advanced classification techniques for accurate and efficient bearing fault diagnosis, significantly enhancing predictive maintenance practices.

Keywords: *Condition monitoring, Multi-scale recurrence quantification analysis, machine learning, fault classification, bearing health monitoring.*