Deep Learning-Based Fault Diagnosis in Electric Motors Using Wavelet Scalograms and Grad-CAM

Safa Bazrafshan

Independent Researcher, Iran

Email: safa.bazrafshan@gmail.com

Introduction

Fault diagnosis in electric motors plays a vital role in industrial automation and reliability. This project proposes a wavelet-based deep learning approach to classify motor conditions using spectrogram images and explain decisions using Grad-CAM. We synthesize motor fault signals and convert them to scalograms, enabling convolutional neural networks (CNNs) to learn discriminative patterns.

Methodology

The workflow consists of five key stages:

1. Synthetic signal generation for three classes: Healthy, Broken Rotor, and Bearing Fault.
2. Feature transformation via Continuous Wavelet Transform (CWT) to create 2D scalogram images.
3. Training a CNN model on these images.
4. Evaluation and classifier comparison.
5. Visualization using Grad-CAM.

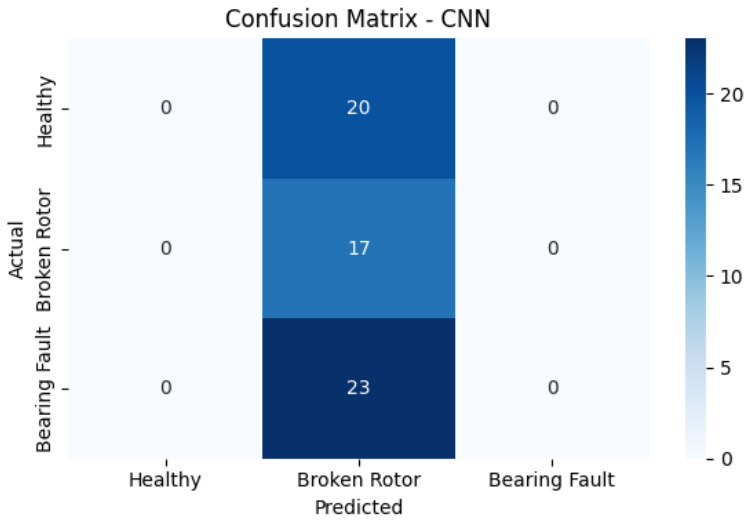

Figure 1: Confusion Matrix (CNN)

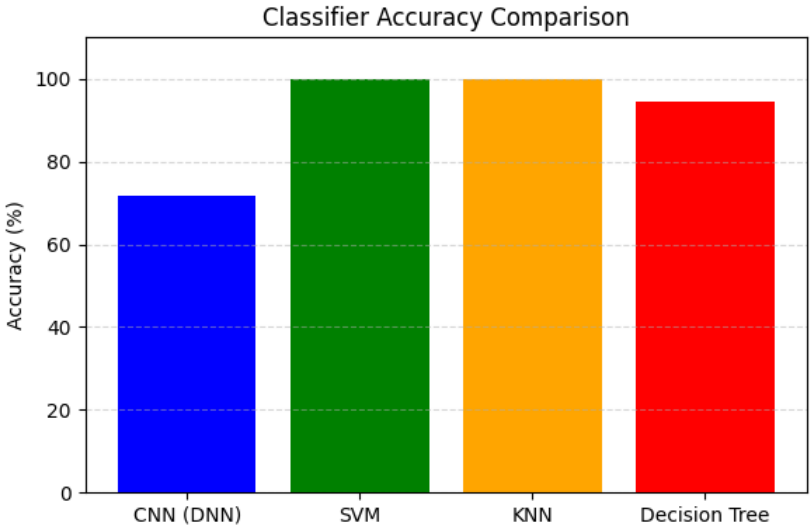

Figure 2: Classifier Accuracy Comparison

Results and Analysis

The CNN achieved a test accuracy of 71.67%, outperforming traditional classifiers on raw signal features. Figures 3–8 illustrate Grad-CAM visualizations highlighting attention regions.

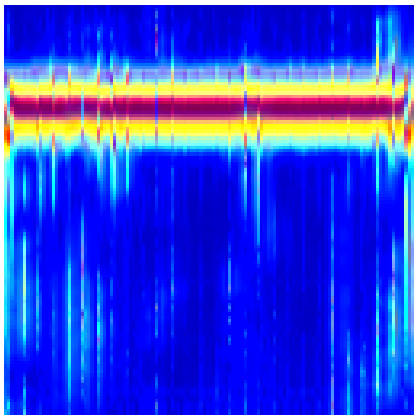

Figure 3 – Grad-CAM (Broken Rotor, sample 1)

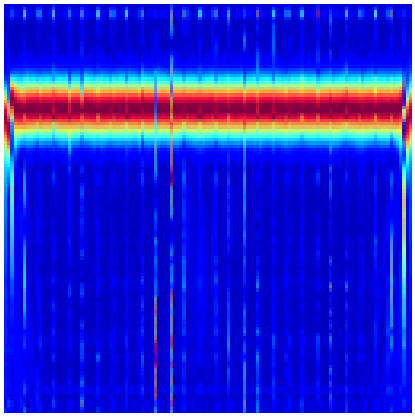

Figure 4 – Grad-CAM (Bearing Fault, sample 1)

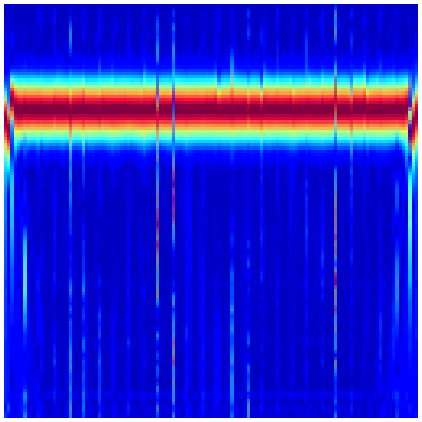

Figure 5 – Grad-CAM (Healthy, sample 1)

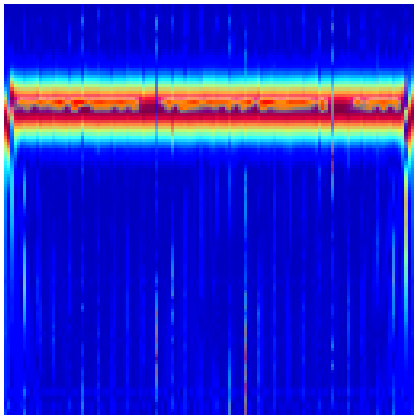

Figure 6 – Grad-CAM (Healthy, sample 2)

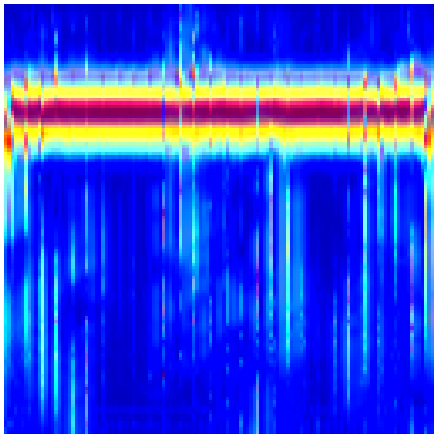

Figure 7 – Grad-CAM (Broken Rotor, sample 2)

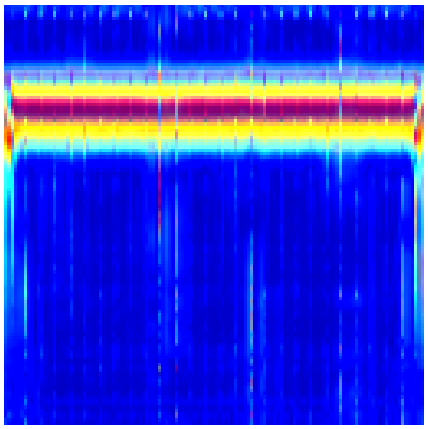

Figure 8 – Grad-CAM (Bearing Fault, sample 2)

Conclusion

This work demonstrates that deep learning models trained on wavelet-based spectrograms can effectively classify motor faults. Moreover, Grad-CAM visualizations provide insight into the model's decisions, supporting its reliability in safety-critical applications.

References

[1] S. Zhang et al., “Deep learning for fault diagnosis of motors,” IEEE Transactions on Industrial Electronics, 2021.

[2] A. Krizhevsky et al., “ImageNet classification with deep CNNs,” NIPS, 2012.

[3] S. Selvaraju et al., “Grad-CAM: Visual explanations from deep networks,” ICCV, 2017.