# Scalogram-Based Deep Learning for Intelligent Fault Diagnosis in Electric Motors

Safa Bazrafshan

Independent Researcher

Email: safa.bazrafshan@gmail.com

## 1. Introduction

Electric motors are fundamental components in industrial systems, and their failure can lead to operational disruptions and financial losses. Timely and accurate fault diagnosis is essential for predictive maintenance.

This project proposes a deep learning-based approach using scalogram images derived from time-domain motor signals. A Convolutional Neural Network (CNN) is trained to classify Healthy, Broken Rotor, and Bearing Fault conditions. Grad-CAM visualization is used to interpret the model's decisions.

## 2. Methodology

The methodology consists of three phases:

1. Signal Generation:

Synthetic motor signals were simulated for three conditions. Each sample captures the electrical behavior associated with a specific fault type.

2. Scalogram Extraction:

Continuous Wavelet Transform (CWT) was used to convert time-domain signals into time-frequency images (scalograms).

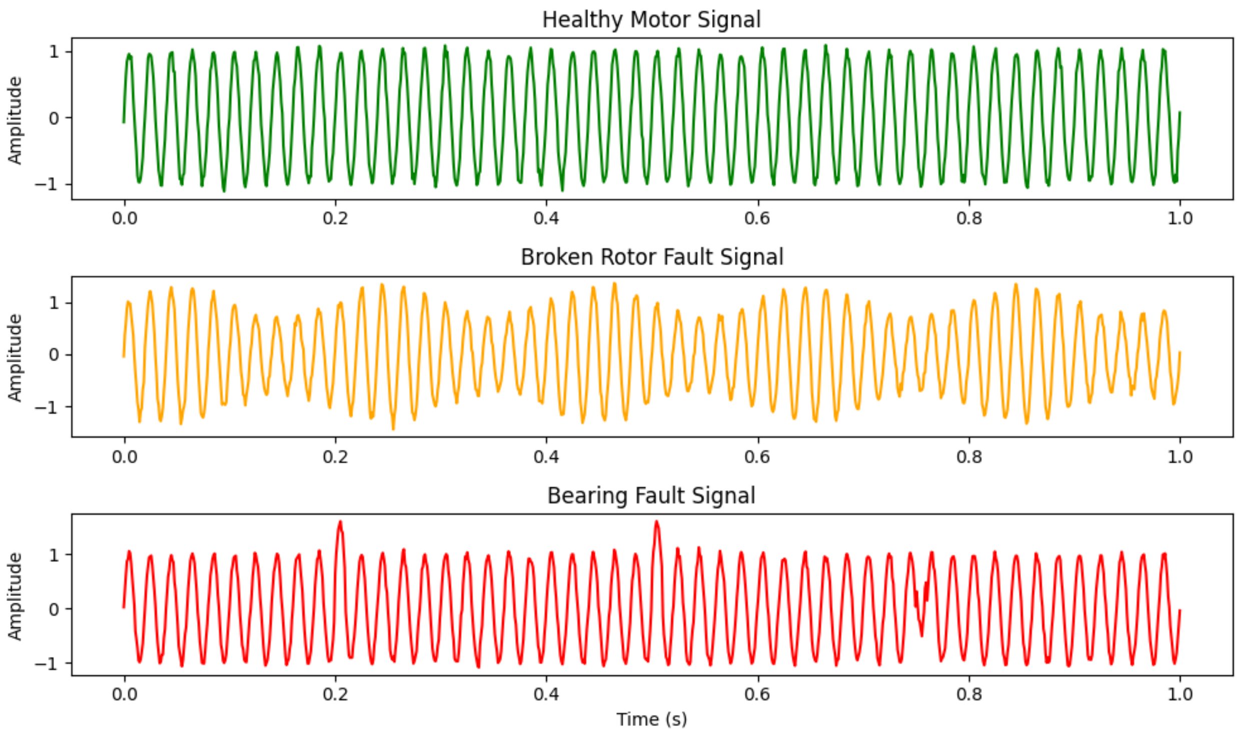


Figure 1. Sample motor signals

CNN Model:

A Convolutional Neural Network was trained on the scalogram dataset. The model's performance was evaluated using a test set and visual explanations were generated using Grad-CAM.

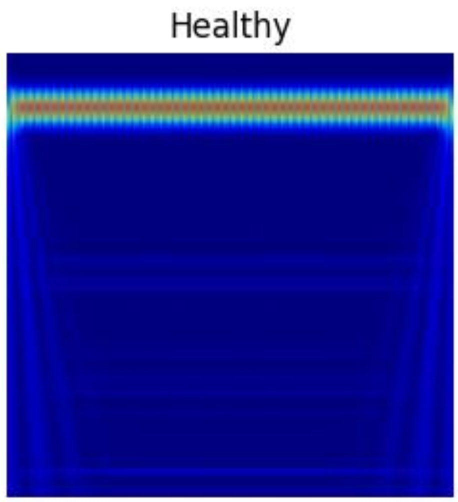


Figure 2. Grad-CAM (Healthy)

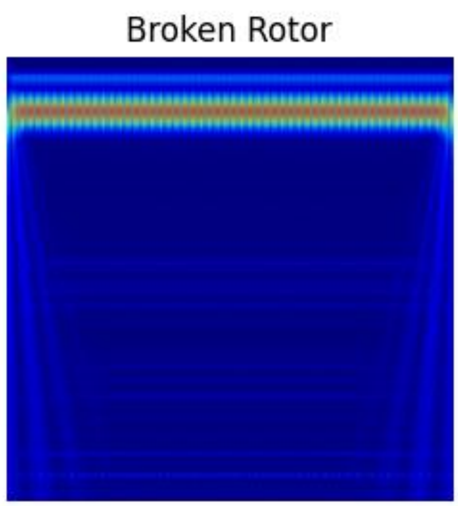


Figure 3. Grad-CAM (Broken Rotor)

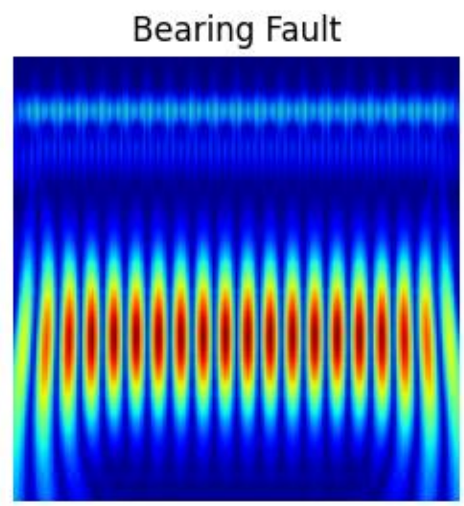


Figure 4. Grad-CAM (Bearing Fault)

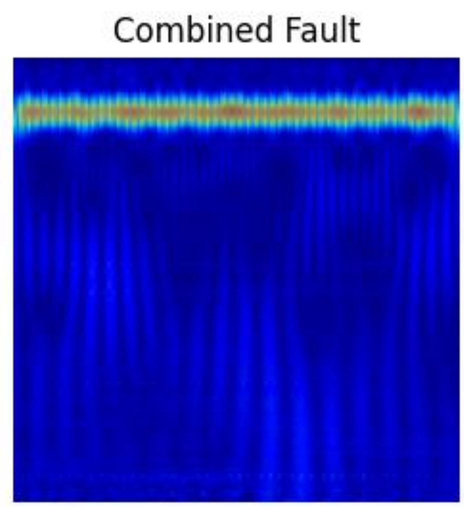


Figure 5. Scalogram of combined fault (multiple issues)

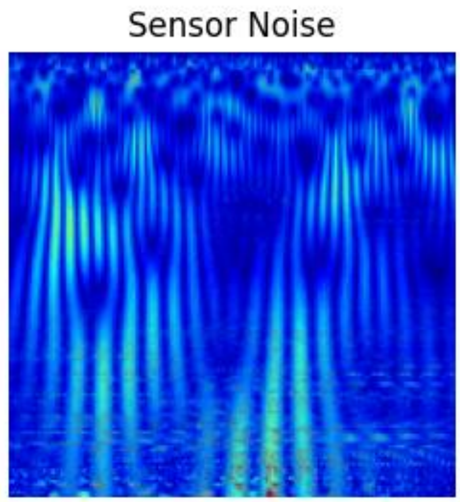


Figure 6. Scalogram of sensor noise (disturbance)

## 3. Results and Visualization

The trained CNN achieved high classification accuracy. The Grad-CAM visualizations provided meaningful insight into which regions of the scalogram contributed most to each classification decision.

To further evaluate the robustness of the model, noisy signals were added, and classification accuracy was compared across classifiers.

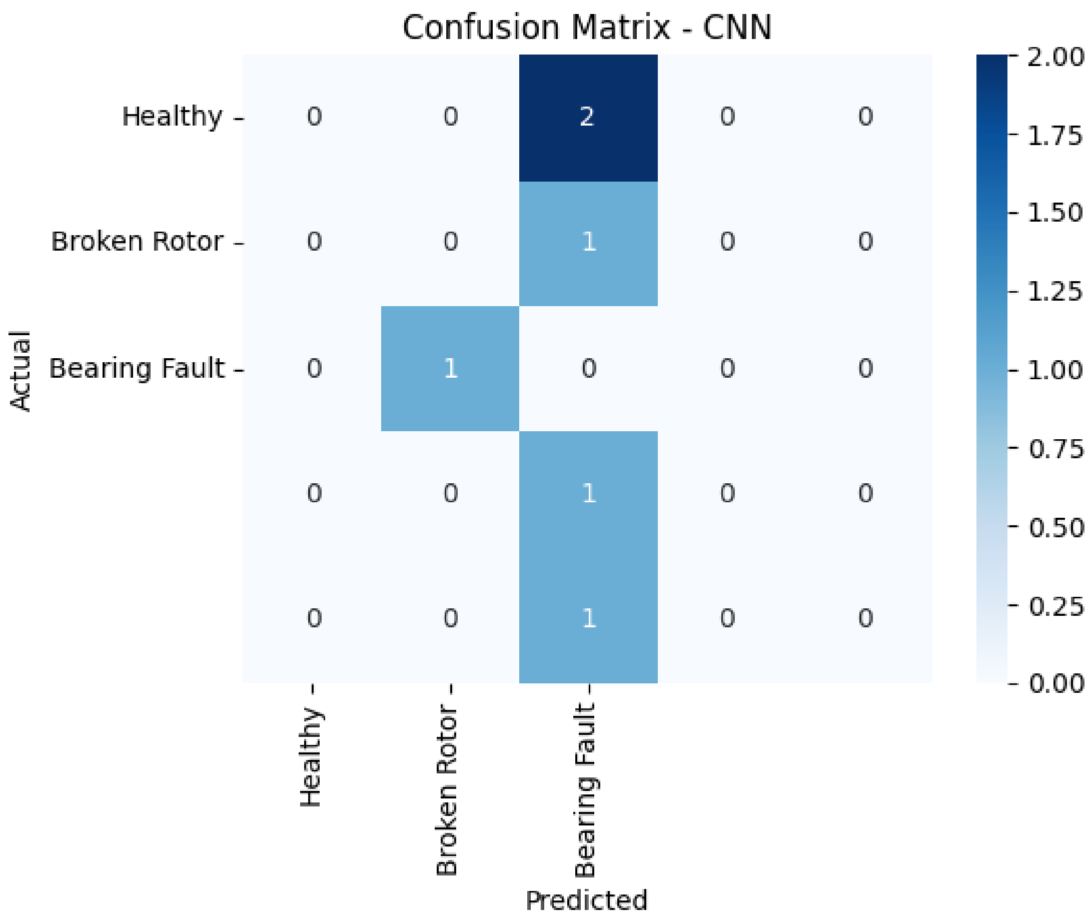


Figure 7. Confusion Matrix of CNN

## 4. Conclusion

This study demonstrates that wavelet-based scalograms, when combined with CNNs, offer an effective and explainable solution for motor fault diagnosis.

The use of Grad-CAM allows transparency in model predictions, enhancing trust in AI-based systems. Future work will explore real-time data acquisition and transfer learning for real-world applications.