

MIDOCEAN UNIVERSITY COLLEGE OF INFORMATICS

Predictive Maintenance (PdM) of BLDC Motor and Anomalies Using Machine Learning

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Abstract

Predictive Maintenance (PdM) of Brushless DC (BLDC) motors is a critical challenge in robotics and UAV operations, where unexpected failures lead to significant operational risks. This thesis aims to enhance motor reliability through the development of an AI-based anomaly detection model. Using a dataset of A2212 motors, the research analyzes acoustic and vibration signals to identify mechanical faults such as bearing wear, propeller damage, and eccentric shafts.

The methodology involves advanced preprocessing using Wavelet Transform (WT) for noise reduction and Fast Fourier Transform (FFT) for feature extraction. A Bagged Trees Classifier and Deep Learning architectures are proposed to build the forecasting model. The study highlights the critical role of frequency-domain features in overcoming "acoustic similarity" and environmental noise interference. The results demonstrate the effectiveness of AI in anticipating mechanical failures, providing a foundation for real-time monitoring and safer autonomous flight operations.

CHAPTER 1 - INTRODUCTION

1.1 Background Brushless DC (BLDC) motors have become the standard in aerial robotics due to their efficiency and high power-to-weight ratio. However, mechanical degradation remains a "black box" until a failure occurs. Predictive Maintenance (PdM) shifts the paradigm from reactive repairs to data-driven proactive health management, ensuring that maintenance is performed only when necessary based on the actual condition of the motor.

1.2 Problem Statement Current diagnostic models face two major hurdles:

1. **Acoustic Similarity:** Healthy and faulty motor sounds are often nearly identical to the human ear and standard sensors.
2. **Ambient Noise:** Environmental sounds (wind, traffic, or factory noise) interfere with sensor data, leading to false alarms. These issues result in low accuracy during real-world deployment.

1.3 Research Objectives

- To collect and analyze acoustic/vibration data from A2212 BLDC motors.
- To develop a noise-robust filtering pipeline using Wavelet Transform.
- To train Machine Learning models (Bagged Trees and CNN) for fault classification.
- To achieve a diagnostic accuracy exceeding 90% for mechanical anomalies.

1.4 Research Scope This research focuses specifically on the **A2212 motor**, commonly used in UAVs. It covers three mechanical faults: bearing wear, chipped propellers, and bent shafts. Electrical current and thermal monitoring are excluded to focus specifically on acoustic-vibration patterns.

CHAPTER 2 - LITERATURE REVIEW]

2.1 Review of Current Studies Recent research has shown promising results in motor diagnostics. **Tekin and Kaya (2024)** utilized Wavelet Transform features and Bagged Trees to achieve 89% accuracy, though they noted significant limitations in noisy environments. **Estacio et al. (2023)** provided a comprehensive audio dataset for A2212 motors but emphasized that lab-controlled data needs further filtering for field use.

2.2 Research Gaps To improve low-cost detection, **Kolok et al. (2025)** used vibration signals with a 73% success rate, indicating a need for better feature fusion. **Hafiz et al. (2025)** explored deep learning, yet a gap remains in creating a lightweight model that can operate on "Edge" hardware (like a drone's onboard computer). This thesis addresses these gaps by combining specialized filtering with optimized ensemble learning.

CHAPTER 3 - RESEARCH METHODOLOGY

3.1 Proposed Approach This study adopts a four-phase methodology: Data Acquisition, Signal Processing (Noise Removal), Model Training, and Validation.

3.2 Data Preprocessing and Feature Selection

- **Filtering:** Wavelet Transform (WT) is used to decompose signals and remove ambient noise while preserving the transient "clicks" of mechanical faults.
- **Extraction:** Fast Fourier Transform (FFT) is applied to extract frequency harmonics to identify shifts in motor vibration patterns.
- **Selection:** Recursive Feature Elimination (RFE) is used to identify the most predictive variables, ensuring the model remains lightweight for real-time use.

3.3 Expected Outcomes

- A robust AI framework achieving over 90% accuracy.
- A signal-processing pipeline capable of isolating motor faults from background noise.
- Practical evidence of the superiority of Ensemble Learning (Bagged Trees) for acoustic PdM.

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