Wavelet-Based Fault Detection in Simulated Signals

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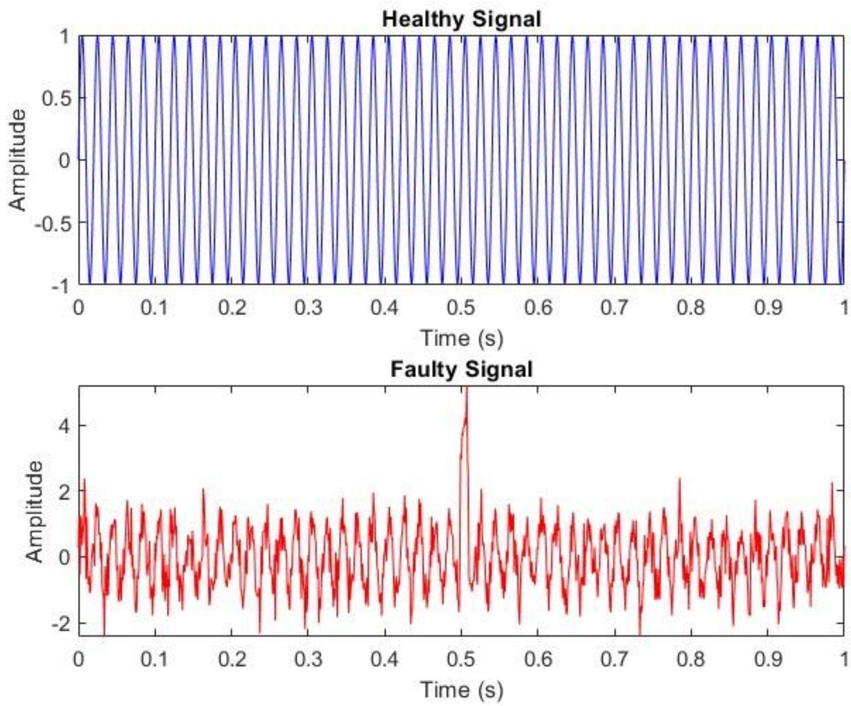
1. Signal Comparison

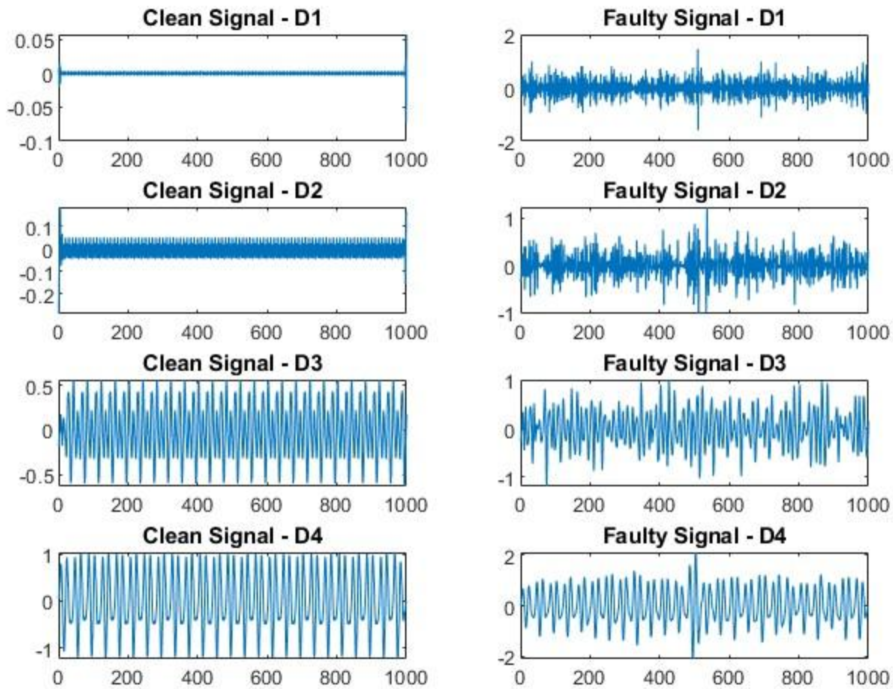


This figure shows the time-domain plots of two signals:

- A healthy signal, represented by a clean sine wave with constant frequency.
- A faulty signal, which includes both random noise and an impulsive disturbance added at the center of the signal.

The difference in signal behavior is clearly visible. The healthy signal maintains a consistent rhythm, while the faulty one exhibits irregularities and distortion.

2. Wavelet Decomposition



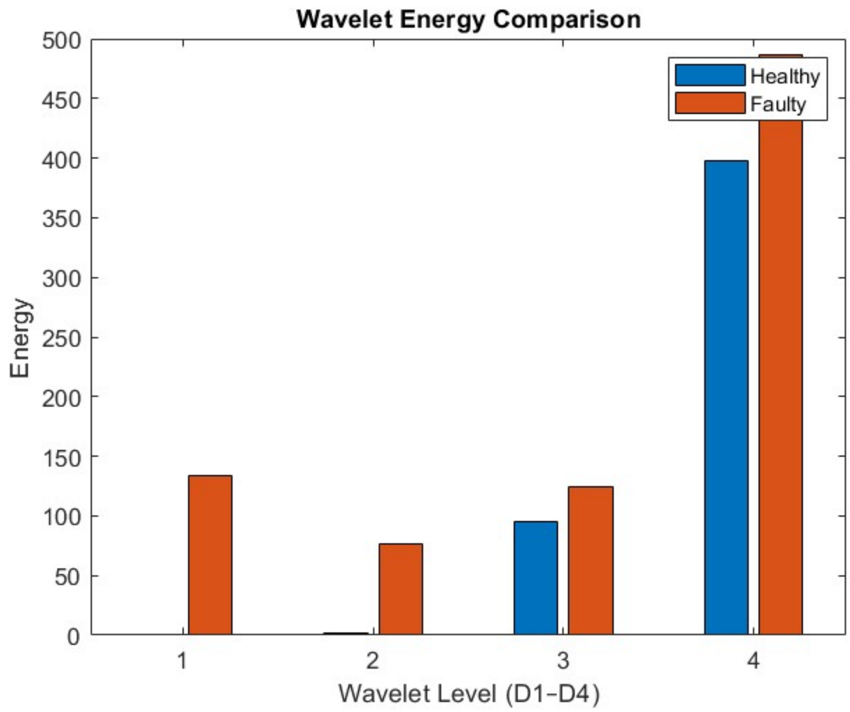
The discrete wavelet transform (DWT) was applied using the Daubechies 4 (db4) wavelet over four decomposition levels. This figure shows the detail coefficients (D1–D4) for both the healthy and faulty signals.

Each row compares the same level across both signals:

- In D1 and D2, the faulty signal exhibits high-frequency noise and spikes.
- In D3 and D4, structural differences emerge more clearly.

These differences demonstrate how wavelet decomposition reveals localized time-frequency changes that are not visible in raw time-domain data.

3. Energy Comparison of Wavelet Coefficients



The energy of each detail level was calculated using the sum of squares of the coefficients.

Level	Healthy Signal	Faulty Signal
D1	0.0157	133.4898
D2	1.3973	76.1315
D3	94.8862	124.2035
D4	397.5863	486.8313

The bar chart in Figure 3 visualizes these energy differences. The faulty signal has significantly higher energy in lower levels (D1 and D2), indicating the presence of high-frequency noise and disturbances.

4. Conclusion

Wavelet-based signal analysis is an effective technique for detecting hidden faults in dynamic signals. While time-domain analysis may miss subtle variations, the wavelet transform captures frequency-localized anomalies at different scales. This example shows how a healthy and a faulty signal, though similar at first glance, differ dramatically in their wavelet energy profiles. This method can be extended to real-world fault detection tasks in mechanical or electrical systems.