Hybrid Sensor-Fusion Framework for Railway Rail Crack Detection: A Comprehensive Review and Proposed Approach

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Abstract: *Railway networks are critical components of modern transportation infrastructure, yet they remain vulnerable to structural degradation, particularly surface and subsurface cracks in rails. Traditional manual inspections, though widely adopted, suffer from limited frequency, human error, and substantial operational costs. In recent years, sensing technologies, machine learning models, and autonomous monitoring systems have emerged as promising tools for reliable and real-time crack detection. This paper reviews existing crack detection techniques, highlights emerging innovations, and proposes a hybrid, sensor-fusion-based framework to enhance accuracy and deployment feasibility. The analysis suggests that integrating visual, vibration, and ultrasonic modalities with deep-learning algorithms can significantly improve detection performance while supporting predictive maintenance. .*

Keywords*: Railway networks*