# Autonomous agriculture machine health monitoring systems using convolutional neural networks optimized by genetic algorithm

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This work presents the complete design, implementation, and validation of a diagnostic system for rotary tedder integrating state-of-the-art sensing, communication, and deep learning methodologies. The core innovation lies in a robust fault detection framework utilizing Convolutional Neural Networks (CNNs), whose architecture is automatically optimized through a Genetic Algorithm (GA), significantly enhancing diagnostic accuracy and adaptability.

A dedicated on-board monitoring unit was engineered, comprising a network of 12 temperature sensors, 5 vibration sensors, and rotation sensors strategically installed on critical driveline components. Data acquisition is managed by an STM32 microcontroller platform, which handles sensor interfacing, preliminary signal processing, and GPS-tagged data logging to an SD card. For real-time telemetry, the unit incorporates GPRS connectivity, transmitting data via the MQTT protocol to a cloud-based platform. This infrastructure enables both online monitoring and offline analysis of machine states.

The core diagnostic intelligence employs a hierarchical analytical methodology. Initial health indicators are derived from time-domain vibration analysis (i.e. RMS, Crest Factor). For advanced fault detection, the system utilizes deep learning. The primary innovation lies in the application of a custom Genetic Algorithm to automate the design and optimization of CNN architectures for fault classification. The GA optimizes the number and type of parallel input pathways (processing raw signals, FFT vectors, spectrograms, and analysis vectors), the configuration of convolutional layers (filter numbers, dimensions, dropout rates), and the structure of dense classification layers (neuron counts, regularization). This approach eliminates suboptimal manual architecture tuning, ensuring a model tailored to the specific characteristics of agricultural machine vibration signatures.

The system was rigorously validated under laboratory and field conditions using SaMASZ P8-890 and Z2-1000 machines. Trained and optimized on data representing healthy operation, gear tooth faults, and lubrication shortages, an initial single-input CNN achieved 99-100% accuracy in distinguishing these fundamental states. A more complex, evolved Multiple-Input, Multiple-Type Parallel CNN demonstrated superior performance in diagnosing nuanced, multi-class fault scenarios. This final architecture, which processes heterogeneous data streams in dedicated parallel sub-networks before a shared classifier, achieved a mean diagnostic accuracy of 92.67% across 9 distinct health conditions, including varying severities of mechanical faults.

***Keywords***: Machine Fault Diagnosis, Convolutional Neural Networks, Genetic Algorithm Optimization, Predictive Maintenance, Smart Agriculture.

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