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Efficiency-Aware Multi-Class Spinal Disorder Classification Using CBAM-Enhanced Lightweight CNNs with Dual-Branch Fusion

[IIUM Engineering Journal](#) • Article • *Open Access* • 2026 • DOI: 10.31436/iiumej.v27i2.4341 [Gunawan, Teddy Surya](#)^a ; [Jannah, Nurul](#)^b; [Kartiwi, Mira](#)^c; [Malik, Noreha Abdul](#)^a^a Electrical and Computer Engineering Dept., International Islamic University Malaysia, Malaysia[Show all information](#)

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Abstract

Spinal X-rays are still often read through manual measurements, yet the patients who most need timely assessment cannot afford delay, inconsistency, or heavy computational pipelines. Motivated by this clinical tension, this study proposes an efficiency-aware deep learning framework for three-class spinal disorder classification that asks a practical question rarely centered in prior work: not only which model is most accurate, but which model is accurate enough, light enough, and fast enough to matter in real screening settings. Using a public dataset of 338 subjects, five lightweight backbones, CBAM-enhanced variants, and a dual-branch fusion model were evaluated through stratified 5-fold cross-validation under multiple balancing strategies, with performance measured by accuracy, precision, recall, F1-score, parameter count, FLOPs, model size, latency, and throughput. The results reveal an unexpected pattern: bigger models do not win. MobileNetV3Small delivers the strongest efficiency-performance balance, reaching an F1-score of 0.962 with only 1.0 million parameters, while the best overall result is achieved by the Fusion_MNv3_MNAS model under

augmentation-only training, with an F1-score of 0.976. Ablation findings further show that attention and fusion are not universally beneficial, but become most effective when paired with sufficient data-driven regularization, and that fine-tuning about 30 of backbone parameters yields the most favorable adaptation. Taken together, these findings show that performance in spinal X-ray classification depends less on model size alone than on the fit between architecture and training strategy. The study therefore offers a concrete and clinically relevant message: lightweight, well-regularized models can match or surpass heavier alternatives while remaining more practical for scalable deployment. Copyright (c) 2026 IIUM Press. This work is licensed under a Creative Commons Attribution-NonCommercial 4.0 International License.
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Author keywords

Attention Mechanism (CBAM); Deep Learning; Efficiency-Aware Evaluation; Lightweight CNN; Spinal Disorder Classification

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