# Evaluating CNN Depth for Multi-Class Bone Tumor Tissue Classification in Histopathology Images

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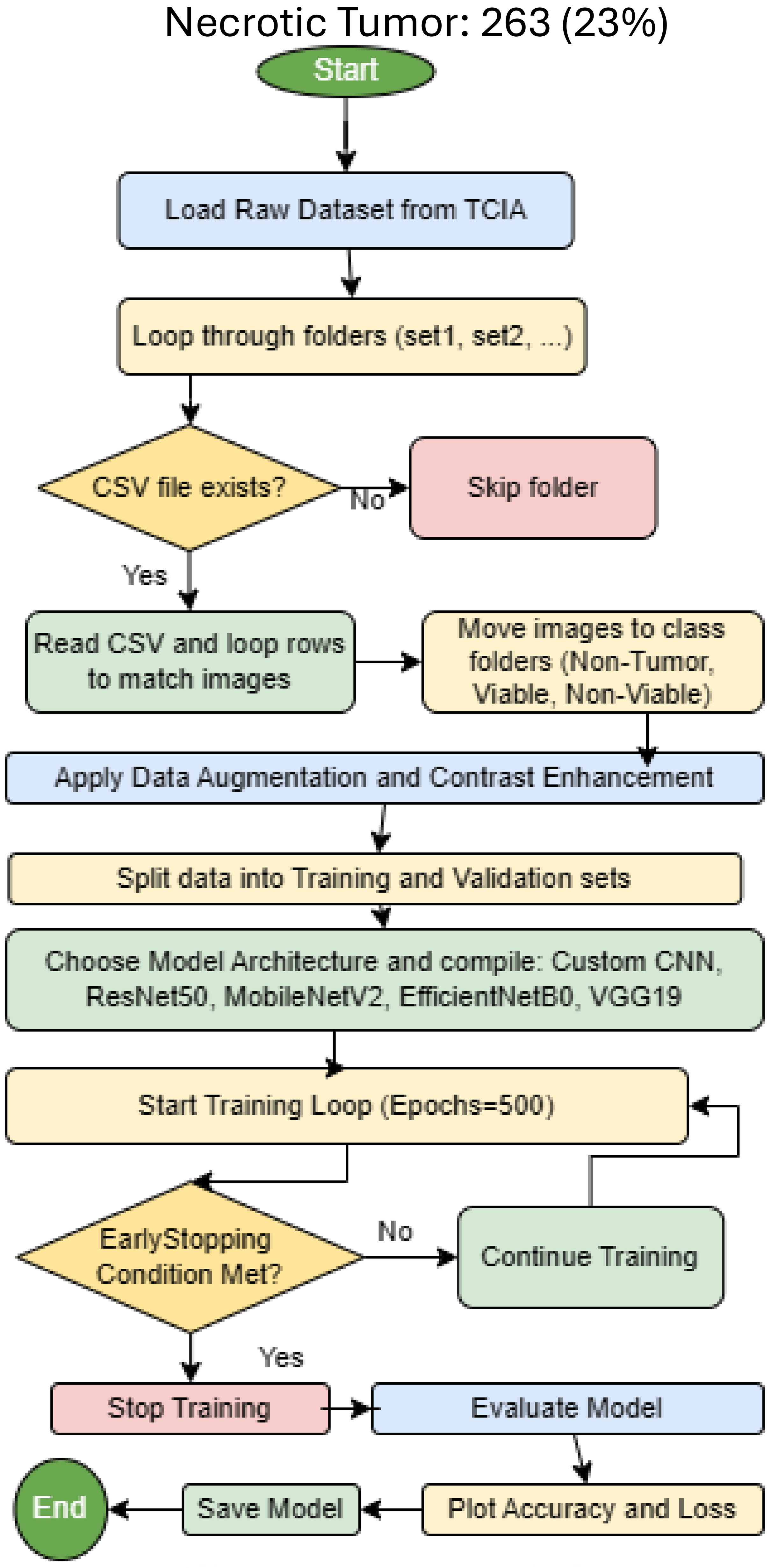
Abstract: This study explores how convolutional neural network (CNN) depth affects the classification of bone tumor tissues in histopathological images. We analyze lightweight custom models versus deeper pre-trained ones, using techniques like contrast enhancement and data augmentation. A shallow CNN achieved **87.44% accuracy**, outperforming deeper models, indicating that optimized lightweight architectures can deliver efficient and accurate multi-class classification.

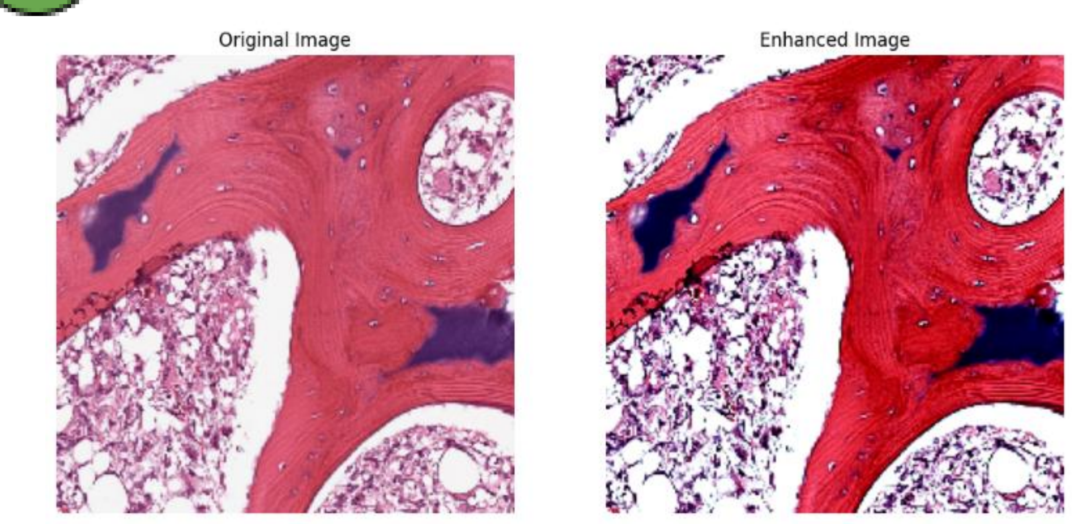
## METHODOLOGY: **Dataset**

Source: **TCIA Osteosarcoma Dataset[1]**, annotated by expert pathologists

Images: **1,144 H&E-stained tiles** from 50 patients

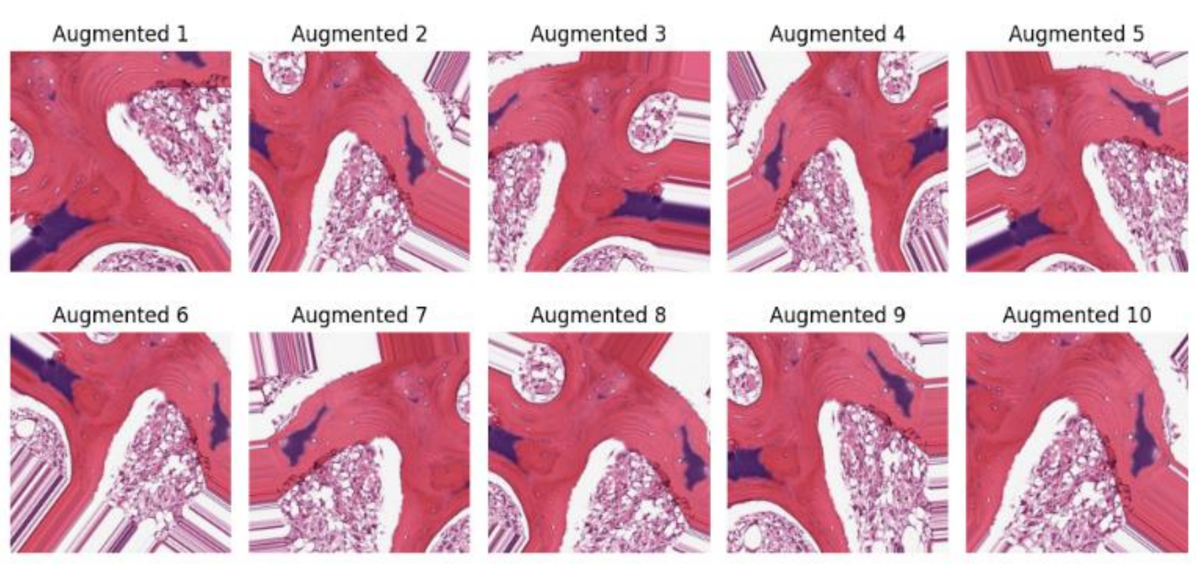
Classes: Non-Tumor: 536 (47%)
Viable Tumor: 345 (30%)
Necrotic Tumor: 263 (23%)




Original and contrast image of "for Case-48-P5-C16-12239-11981.jpg"

Augmented image




## RESULTS AND DISCUSSION

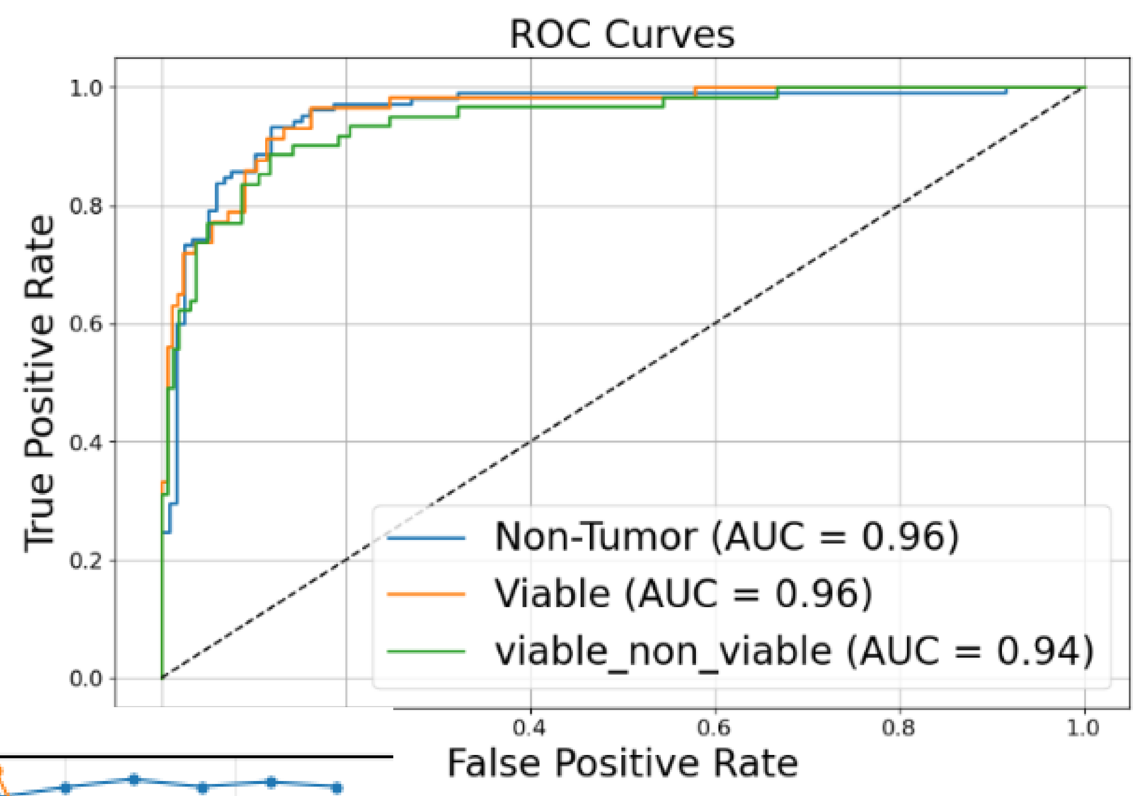
Data Augmentation Strategies and Medical Justifications with performance evaluation

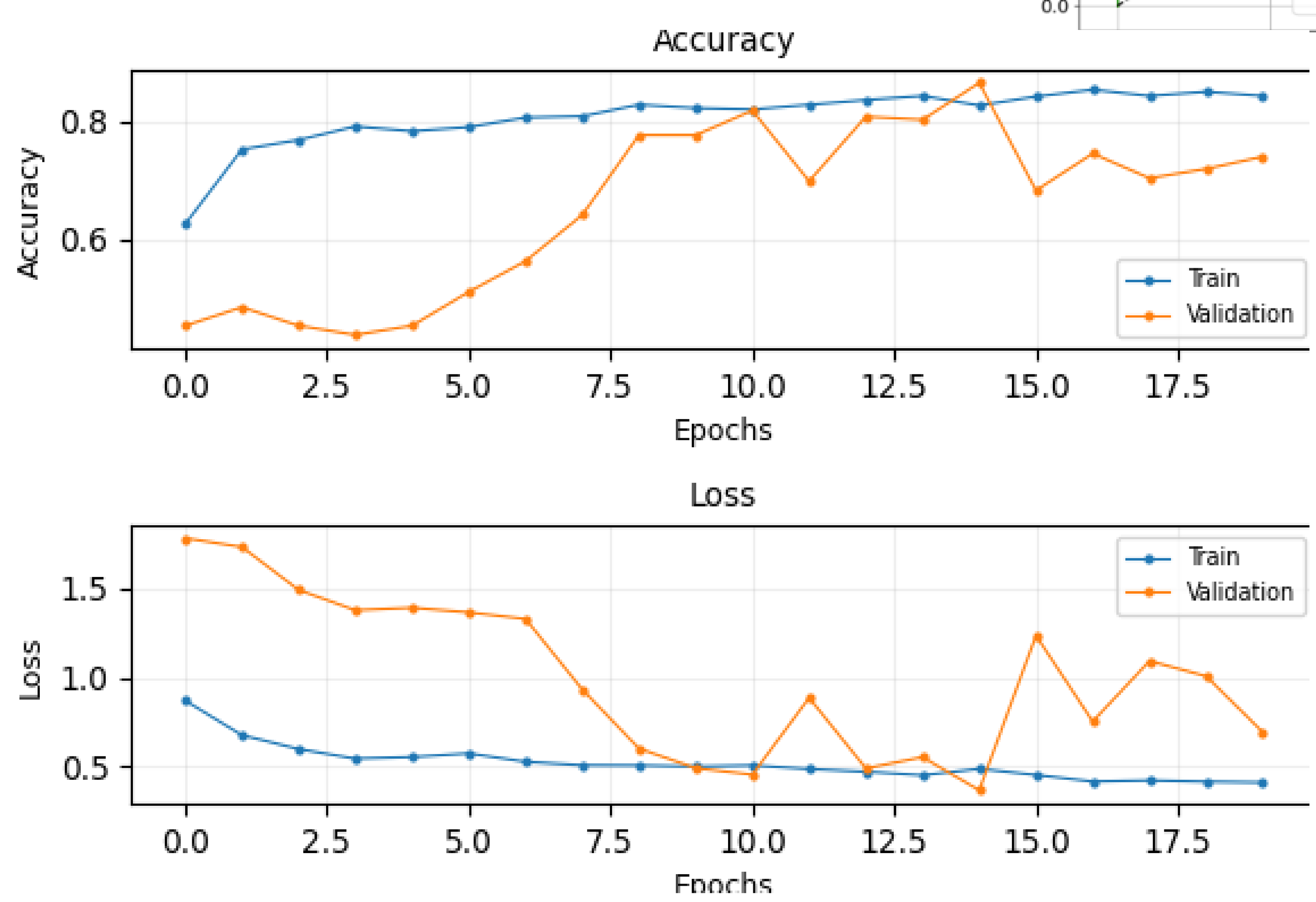
| # | Rotation | Width Shift | Height Shift | Zoom | Flip | Validation Loss | Validation Accuracy | Medical Justification |
|---|---|---|---|---|---|---|---|---|
| 1 | 10° | 0.1 | 0.1 | 0.1 | ✗ | 1.4183 | 0.4709 | Mild variation simulating scanner misalignment |
| 2 | 20° | 0.2 | 0.2 | 0.2 | ✓ | 0.6479 | 0.7534 | Moderate variability; flip handles orientation issues |
| 3 | 30° | 0.3 | 0.3 | 0.3 | ✓ | 0.3594 | 0.8744 | Strong regularization to reduce overfitting |
| 4 | 0° | 0.0 | 0.0 | 0.0 | ✗ | 0.6253 | 0.7758 | Baseline with no augmentation |
| 5 | 0° | 0.0 | 0.3 | 0.1 | ✗ | 1.0264 | 0.4709 | Mimics vertical slice shifts in imaging |
| 6 | 5° | 0.05 | 0.05 | 0.4 | ✗ | Unable to process | | Focused zoom simulates closeness to ROI (tumor core), useful in histology. |
| 7 | 0° | 0.0 | 0.0 | 0.0 | ✓ | 0.3960 | 0.8475 | Flip only; safe for symmetric histology structures |
| 8 | 40° | 0.0 | 0.0 | 0.1 | ✗ | 0.3675 | 0.8565 | Enhances rotational invariance for irregular shapes |
| 9 | 8° | 0.05 | 0.05 | 0.05 | ✓ | 0.4141 | 0.8475 | Gentle, general-purpose augmentation |
| 10 | 5° | 0.4 | 0.4 | 0.0 | ✗ | 0.4374 | 0.8161 | Strong translation to test spatial variability |

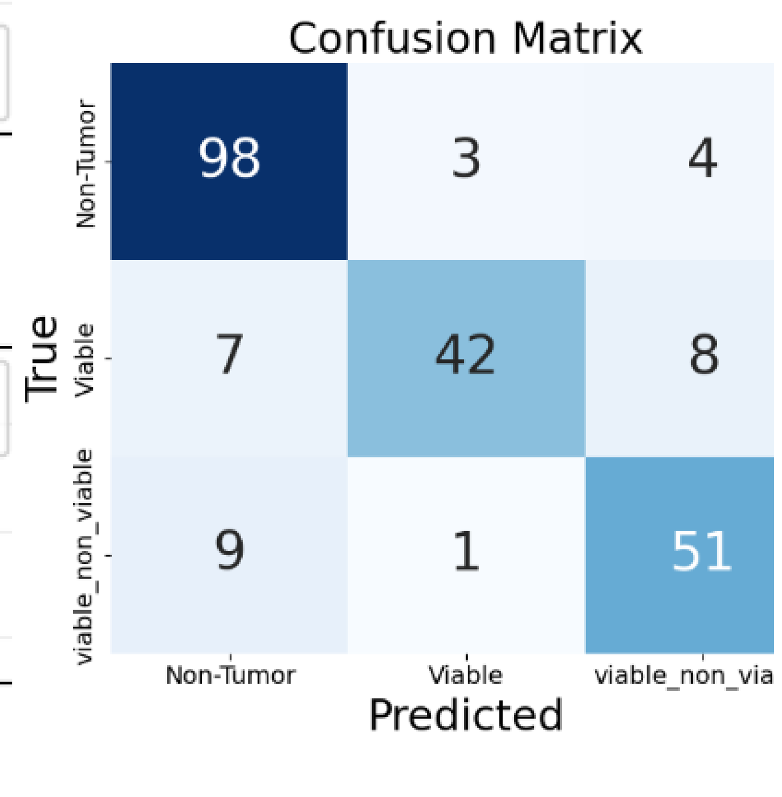
Different Model Performance

| Contrast Enhancement | Architecture | Early Stopped Epoch | Validation Loss | Validation Accuracy |
|---|---|---|---|---|
| ✗ | Custom 2-Block CNN | 20 | 0.3594 | 0.8744 |
| ✓ | Custom 2-Block CNN | 19 | 0.4116 | 0.8475 |
| ✗ | Custom 3-Block CNN | 19 | 1.0579 | 0.4709 |
| ✓ | Custom 3-Block CNN | 13 | 1.0583 | 0.4709 |
| ✗ | ResNet50 | 16 | 0.5403 | 0.7982 |
| ✓ | ResNet50 | 18 | 0.5734 | 0.7631 |
| ✗ | MobileNetV2 | 16 | 0.5956 | 0.7758 |
| ✓ | MobileNetV2 | 10 | 0.7728 | 0.6637 |
| ✗ | EfficientNetB0 | 11 | 0.6180 | 0.6951 |
| ✓ | EfficientNetB0 | 10 | 0.7062 | 0.6323 |
| ✗ | VGG19 | 8 | 0.6304 | 0.7309 |
| ✓ | VGG19 | 24 | 1.0019 | 0.7354 |

This study shows that a lightweight CNN with targeted augmentation (30° rotation, 30% shift, zoom, and flipping) achieved 87.44% accuracy, demonstrating its effectiveness for assisting pathologists in osteosarcoma tissue classification.




custom 2-block CNN without contrast enhancement

References: [1]Clark, K., et al. (2013). The Cancer Imaging Archive (TCIA): maintaining and operating a public information repository. Journal of Digital Imaging, 26(6), 1045–1057.

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