Impact of Noise Modeling on MRI Images Using Deep Learning

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Introduction

15% of medical images are MRI images

Datasets ~ 2000 images

Lack of data due to high cost

Nature of the images : Rician Noise

→ Optimization with Data Augmentation

Dataset

2000 Brain Tumor MRI images for binary classification (tumor / no tumor)

Images resized to 224×224 pixels

Standard Data Augmentation : Rotation, Horizontal Flip, Translation

Steps

Three preprocessing strategies :

No noise augmentation → Baseline

Baseline + Gaussian noise addition

Baseline + Rician noise addition (MRI-specific)

Rice Law

$$X \sim \mathcal{N}(\nu\cos(\theta), \sigma), Y \sim \mathcal{N}(\nu\sin(\theta), \sigma), X \perp Y$$

$$R = \sqrt{X^2 + Y^2} \sim Rice(\nu, \sigma)$$

Signal-to-noise Ratio : $SNR = \frac{\nu}{\sigma}$

$SNR \gg 1$: $\mathrm{Rice}(\nu, \sigma) \approx \mathcal{N}(\nu, \sigma)$, gaussian regime

$SNR = 0$: $\mathrm{Rice}(\nu, \sigma) \approx Rayleigh(\nu, \sigma)$, black pixels become more grey

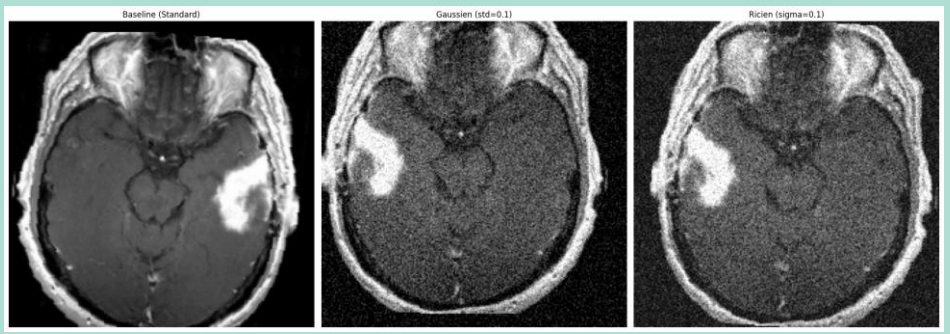
$SNR \simeq 1$, Rician regime, strong asymmetry, appears in the tissues → Rician bias

MRI

Noised Signal

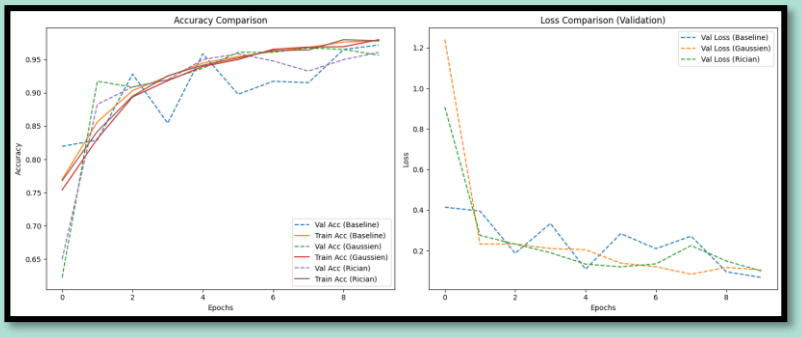
Magnitude : $\sqrt{(S_{true} + \epsilon_{Re})^2 + \epsilon_{Im}^2}$ → Rice Law

Image Augmentation



Images from the baseline/gaussian/rician training sets

Model Training

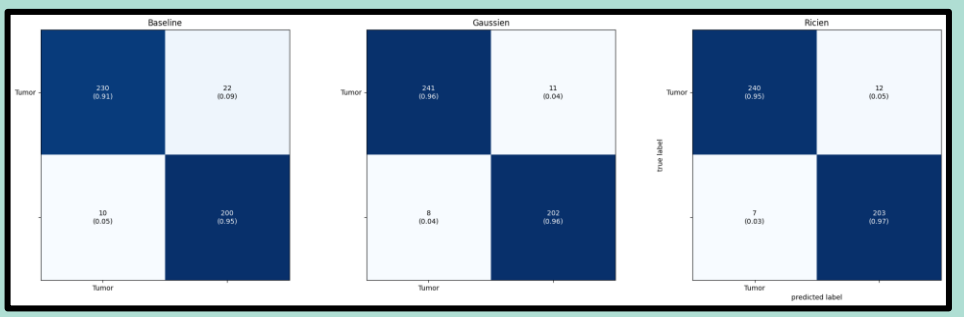


ResNet50 pre-trained, Frozen backbone, Fine-tuned classifier, Adam optimizer

Results

Noise Type	Val Accuracy	Training Loss
Baseline	0.9587	0.1504
Gaussian	0.9565	0.0699
Rician	0.9609	0.0634

Classification on test set



Conclusion

Marginal performance differences between the baseline, Gaussian noise, and Rician noise configurations.

Problem: **Limited** dataset size

Possible solution: **Aggregate** multiple MRI images datasets

Discussion

Adding Rician noise leads to more **realistic** data augmentation.

Further experiments:

- More advanced **architectures**(DenseNet, ConvNeXt, Dino)
- Extending to other **tasks** (muti-class classification, segmentation, object detection)
- Evaluate the method on other **datasets**