Brain Tumor Detection Using ResNet18 – Initial vs. Fine-Tuned Model

---

📌 Objective

To implement and compare the performance of two configurations of the ResNet18 convolutional neural network for brain tumor classification using MRI images. The study aims to evaluate both transfer learning (with frozen feature extractors) and fine-tuning strategies (with selectively unfrozen layers) on model accuracy and generalization.

🧠 Model Overview: ResNet18

ResNet18 is a residual neural network consisting of 18 layers with skip connections that help avoid vanishing gradient problems during deep training. It was pretrained on ImageNet and adapted to a 4-class brain tumor classification task.

- **Initial Model:** All convolutional layers frozen; only the final fully connected (FC) classifier layers are trained.
- **Fine-Tuned Model:** Final ResNet blocks (`layer3`, `layer4`) and the FC layers are unfrozen and jointly trained.

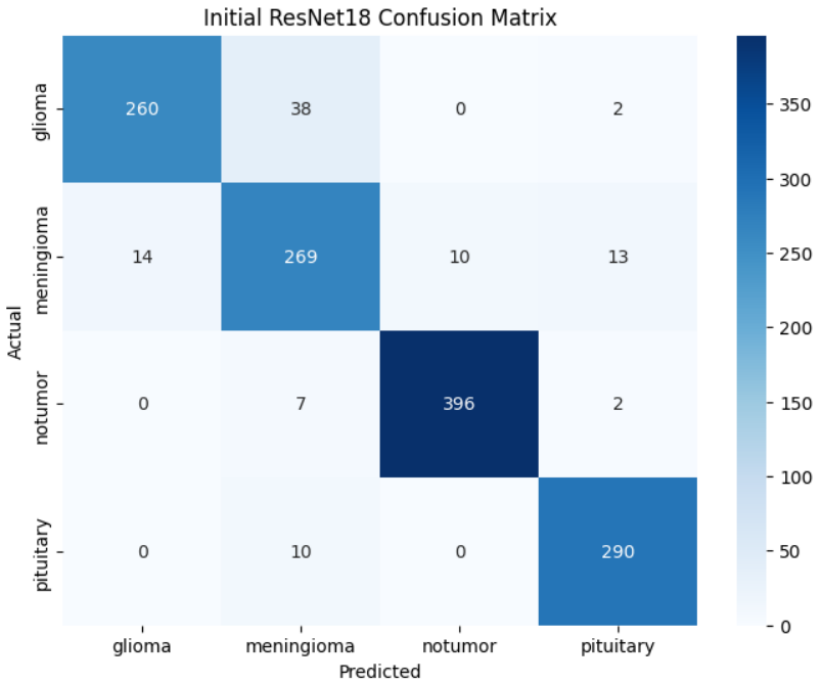
⚙️ Experimental Setup

- **Dataset:** masoudnickparvar/brain-tumor-mri-dataset from KaggleHub
- **Input size:** 224 × 224 × 3
- **Classes:** Glioma, Meningioma, Pituitary, No Tumor
- **Data Split:**
  - Training set: 85% of training folder
  - Validation set: 15% of training folder
  - Test set: Entire testing folder
- **Transforms:** Resize, Normalize (mean=0.5, std=0.5), Tensor conversion
- **Loss Function:** CrossEntropyLoss
- **Optimizers:**
  - Initial Model: `Adam (lr=0.001)` on classifier layers
  - Fine-Tuned Model: `Adam (lr=0.0001)` on selected layers
- **Early Stopping:** Patience = 5 epochs
- **Hardware:** CUDA-enabled GPU (if available)

🏋️ Initial Model Training (Frozen Backbone)

- **Training Duration:** Up to 60 epochs with early stopping
- **Layers Trained:** Only the final classifier (`fc`)
- **Saved Best Model:** `best_brain_tumor_resnet18.pth`
- **Final Test Accuracy: 92.68%**

🔍 Evaluation – Initial Model

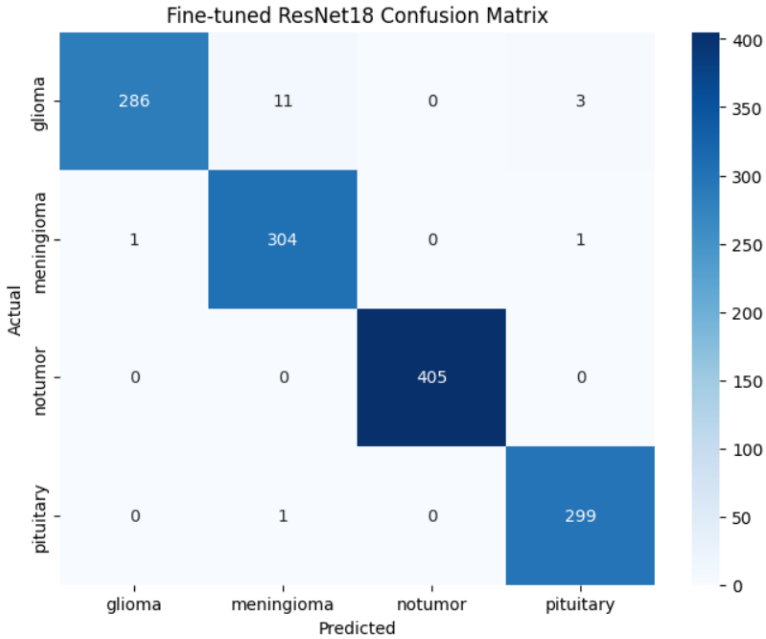



```
Evaluation: Initial ResNet18 Model
              precision    recall  f1-score   support

      glioma       0.95      0.87      0.91       300
  meningioma       0.83      0.88      0.85       306
     notumor       0.98      0.98      0.98       405
   pituitary       0.94      0.97      0.96       300

    accuracy                           0.93      1311
   macro avg       0.92      0.92      0.92      1311
weighted avg       0.93      0.93      0.93      1311
```

🔧 Fine-Tuned ResNet18 Model (Unfrozen `layer3`, `layer4`, `fc`)

- **Training Duration:** Up to 60 epochs with early stopping
- **Layers Trained:** `layer3`, `layer4`, and `fc`
- **Saved Best Model:** `best_brain_tumor_resnet18_finetuned.pth`
- **Final Test Accuracy: 98.70%**

🔍 Evaluation – Fine-Tuned Model




```
Evaluation: Fine-tuned ResNet18 Model
              precision    recall  f1-score   support

      glioma       1.00      0.95      0.97       300
  meningioma       0.96      0.99      0.98       306
     notumor       1.00      1.00      1.00       405
   pituitary       0.99      1.00      0.99       300

    accuracy                           0.99      1311
   macro avg       0.99      0.99      0.99      1311
weighted avg       0.99      0.99      0.99      1311
```

📊 Comparison Summary

Metric	Initial ResNet18	Fine-Tuned ResNet18
Training Scope	FC only	FC + deeper layers
Test Accuracy	92.68%	**98.70%**
Overfitting Risk	Low	Moderate (managed by early stopping)
Generalization	Good	Excellent
Training Time	Shorter	Longer
Improvement Areas	Misclassifications in complex images	Strong correction of previous errors

---

🎯 Conclusion

The fine-tuned ResNet18 model achieved a significant performance boost compared to the initial transfer learning model by leveraging deeper feature layers (`layer3`, `layer4`) for task-specific learning. The accuracy increased from **92.68% to 98.70%**, showcasing the effectiveness of selective fine-tuning in medical image classification tasks.