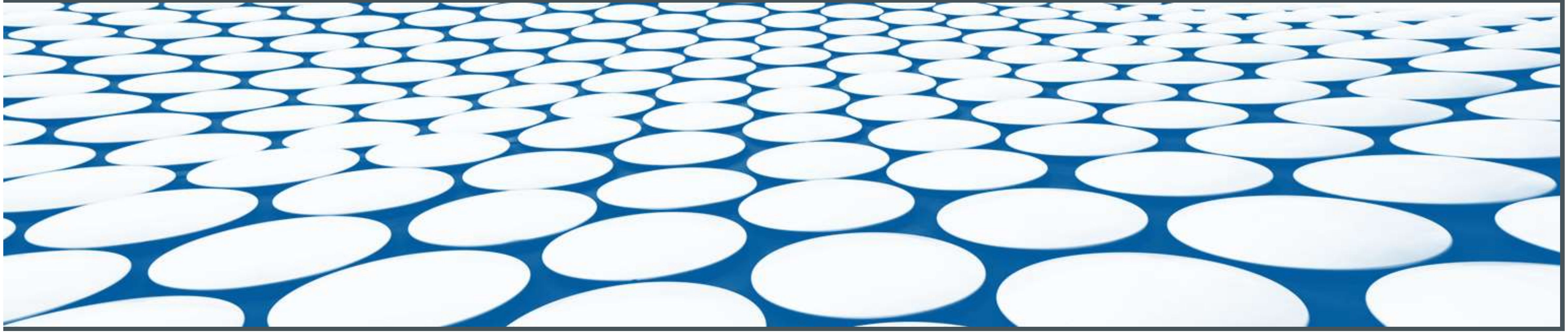
5502 GROUP #1 MIDTERM REPORT

BRAIN TUMOR CLASSIFICATION USING CNNS AND GRAD-CAM



1. Introduction

Objectives

- Develop an automated CNN model for accurate brain tumor classification.
- Enhance image interpretability using CLAHE (Contrast Limited Adaptive Histogram Equalization).
- Evaluate model performance with metrics such as accuracy, precision, recall, and F1-score.
- Incorporate Grad-CAM to visualize regions contributing to predictions, ensuring clinical explainability.

2. Dataset Description – Data Source

Data Source:

The dataset consists of MRI scans from Kaggle, organized into:

- **Training Set**: Contains labeled images (5,712 samples) across four categories.
- **Testing Set**: Contains 1,311 images for validation.

Classes:

- **Glioma**: Tumors arising from glial cells.
- **Meningioma**: Tumors originating in the meninges.
- **Pituitary**: Tumors in the pituitary gland.
- **No Tumor**: Normal brain scans.

2. Dataset Description – Data Distribution

Class	Training Samples	Testing Samples
Glioma	1,321	300
Meningioma	1,339	306
No Tumor	1,595	405
Pituitary	1,457	300

3. Model Architecture

CNN Structure

The CNN consists of the following layers:

- **Convolutional Blocks:**
  - Three blocks of **Conv2D + MaxPooling + Dropout** for feature extraction.
  - Filters: 32 → 64 → 128.
  - ReLU activation.
- **Dense Layers:**
  - **Flatten** layer to transition from spatial to dense features.
  - Fully connected layers (128 neurons) with Dropout (0.5) for regularization.
  - **Softmax** output for 4-class classification.

Loss Function: sparse_categorical_crossentropy
Optimizer: Adam
Metrics: Accuracy

4. Methodology

Preprocessing Steps

- **Grayscale Conversion:** RGB → Single-channel for efficiency.
- **Resizing:** All images standardized to **150×150 pixels**.
- **CLAHE Enhancement:** Adaptive contrast improvement.
- **Normalization:** Pixel values scaled to **[0, 1]**.

Model Training

- **Epochs:** 10
- **Batch Size:** 32
- **Validation Split:** 20% held-out for validation.

5. Results – Training Performance

Epoch	Training Accuracy	Validation Accuracy	Training Loss	Validation Loss
1	54.12%	68.73%	1.0588	0.6899
10	95.78%	93.59%	0.1186	0.1685

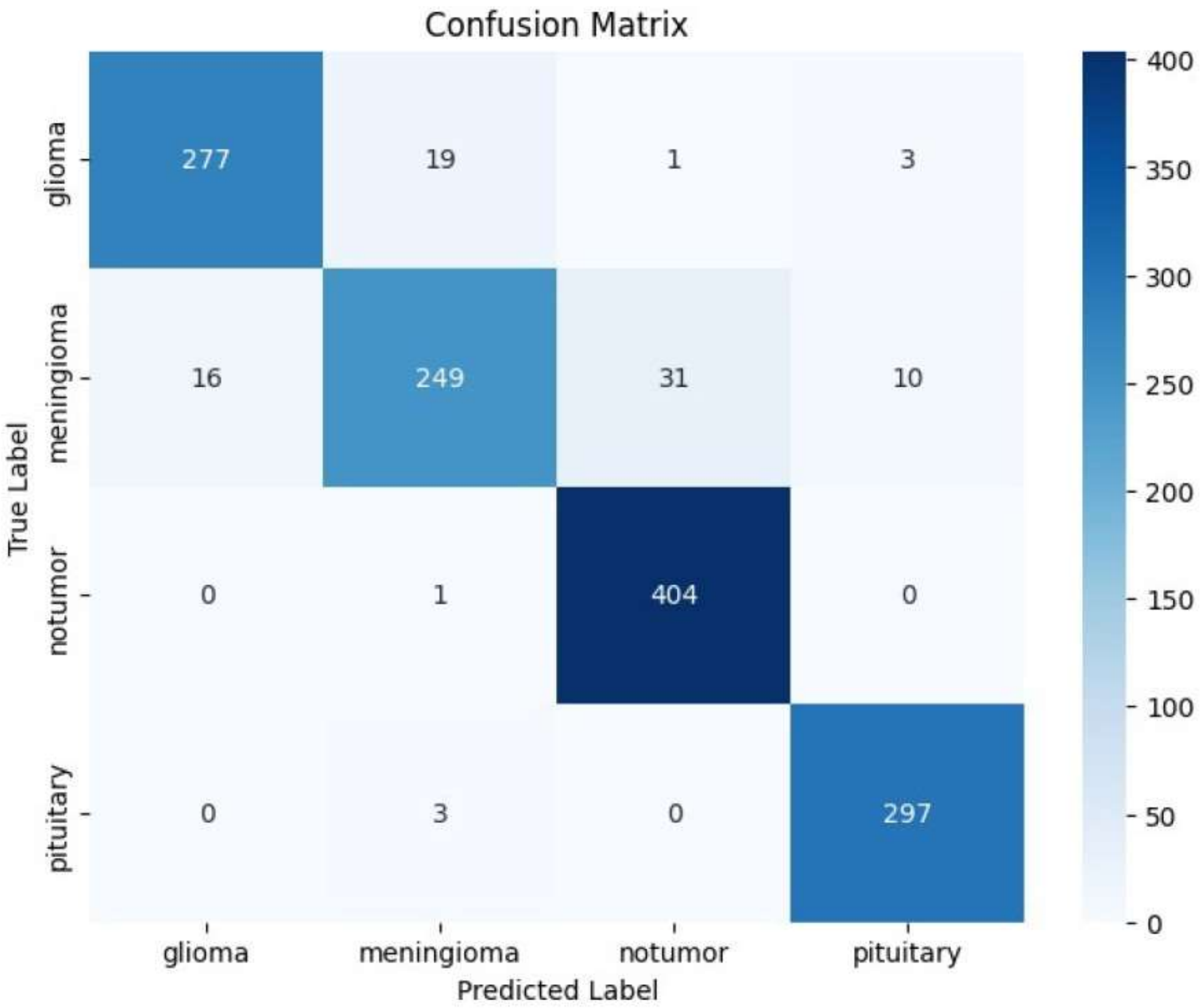
Final Test Metrics:

- Overall Accuracy: 94%
- Precision (Macro Avg): 0.94
- Recall (Macro Avg): 0.93
- F1-Score (Macro Avg): 0.93

5. Results – Class-Specific Performance

Class	Precision	Recall	F1-Score	Support
Glioma	0.95	0.92	0.93	300
Meningioma	0.92	0.81	0.86	306
No Tumor	0.93	1.00	0.96	405
Pituitary	0.96	0.99	0.97	300

5. Results – Confusion Matrix



Key Observation: Meningioma had lower recall (81%), with some confusion with glioma and no-tumor classes.

6. Visualizations - Accuracy & Loss Curves

Training Curves

- **No Overfitting:** Validation accuracy closely follows training accuracy.

Grad-CAM Interpretability

Grad-CAM Output

- The model accurately identifies tumor-localized regions.
- Highlights model transparency in clinical decision-making.

7. Interpretation and Discussion

Key Findings

- The CNN achieved **94% accuracy**, demonstrating strong generalization.
- **Grad-CAM** confirmed that the model focuses on **medically relevant regions** for classification.
- **Meningioma misclassifications** suggest potential areas for improvement.

Challenges & Solutions

Challenge	Solution
Low contrast in MRI scans	CLAHE enhancement improved feature visibility.
Class imbalance	Future work could incorporate weighted loss or augmentation.
Model explainability	Grad-CAM helps build clinician trust.

8. Conclusion

This project developed an **accurate (94%) and interpretable** CNN model for brain tumor classification. Key contributions include:

- **Preprocessing with CLAHE** for improved image quality.
- **Robust CNN architecture** with regularization to prevent overfitting.
- **Grad-CAM explanations** for clinical interpretability.

Future Work:

- **Data Augmentation** for better meningioma recall.
- **Transfer Learning** with ResNet/VGG for higher accuracy.
- **Larger, multi-center datasets** for improved generalizability.

9. References

1. Selvaraju, R. R., et al. "Grad-CAM: Visual Explanations from Deep Networks." *ICCV 2017.*
2. CLAHE: https://docs.opencv.org/3.4/d5/daf/tutorial_py_histogram_equalization.html
3. Dataset Source: Kaggle Brain Tumor MRI Dataset. https://www.kaggle.com/datasets/masoudnickparvar/brain-tumor-mri-dataset

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