A Viskores-Enhanced Vision Transformer Framework for MRI-Based Cancer Image Classification

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ABSTRACT

Scientific visualization is widely used to interpret complex data, but its potential to enhance deep learning remains underexplored. This work investigates whether Viskores-generated visualization features can improve Vision Transformer (ViT) performance for brain tumor MRI classification on the Frontier supercomputer. We compare a raw MRI baseline with a visualization-enhanced pipeline using median, Sobel, Laplacian, texture, Otsu, and morphological preprocessing. The best visualization-enhanced approach achieved **95.50% accuracy**, compared with **91.94%** for the raw-image baseline.

BACKGROUND

- **MRI-based brain tumor classification** can benefit from deep learning, but raw images may not explicitly emphasize diagnostically relevant structures.
- **Vision Transformers (ViTs)** [1] provide a powerful framework for image classification by modeling global image relationships.
- **Scientific visualization** traditionally supports interpretation of complex data, but its potential to enhance machine-learning representations remains underexplored.
- **Viskores** [2] provides scalable visualization and data-processing operations suitable for HPC environments.

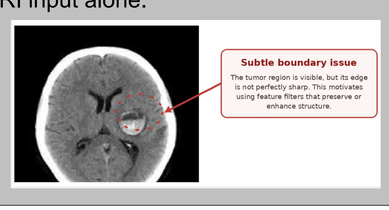


PROBLEM STATEMENTS

- Generate scientific image features from 2D brain MRI images using Viskores, ncluding edge, texture, segmentation, and intensity-based features.
- Compare the raw-image ViT model with the feature-enhanced ViT model using accuracy, F1-score, ROC-AUC, and confusion matrix results.

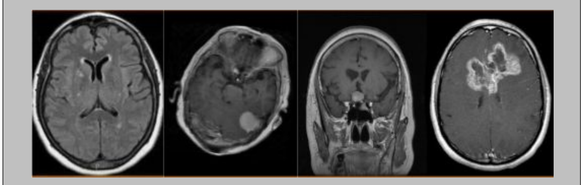
OBJECTIVES

- **Improve the classification performance** by using Viskores-generated MRI features to help ViT improve classification accuracy compared with raw MRI input alone.



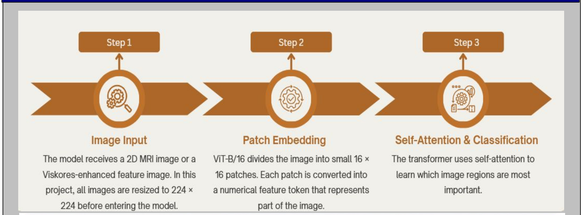
DATASETS

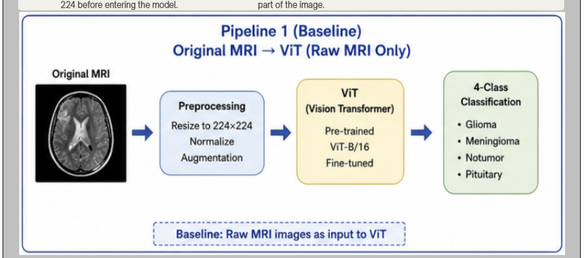
- Public 2D Brain MRI Images: The dataset contains 7,200 human brain MRI images categorized into four classes;
  - Glioma
  - Meningioma
  - Pituitary tumor
  - No tumor

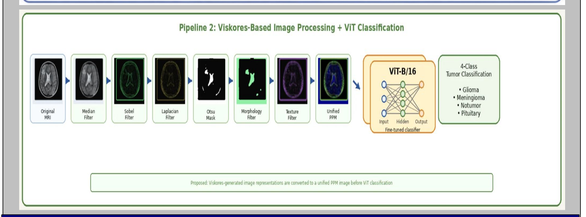


- **Training**
  - glioma/ (1400 images)
  - meningioma/ (1400 images)
  - pituitary/ (1400 images)
  - notumor/ (1400 images)
- **Testing**
  - glioma/ (400 images)
  - meningioma/ (400 images)
  - pituitary/ (400 images)
  - notumor/ (400 images)

METHODOLOGY



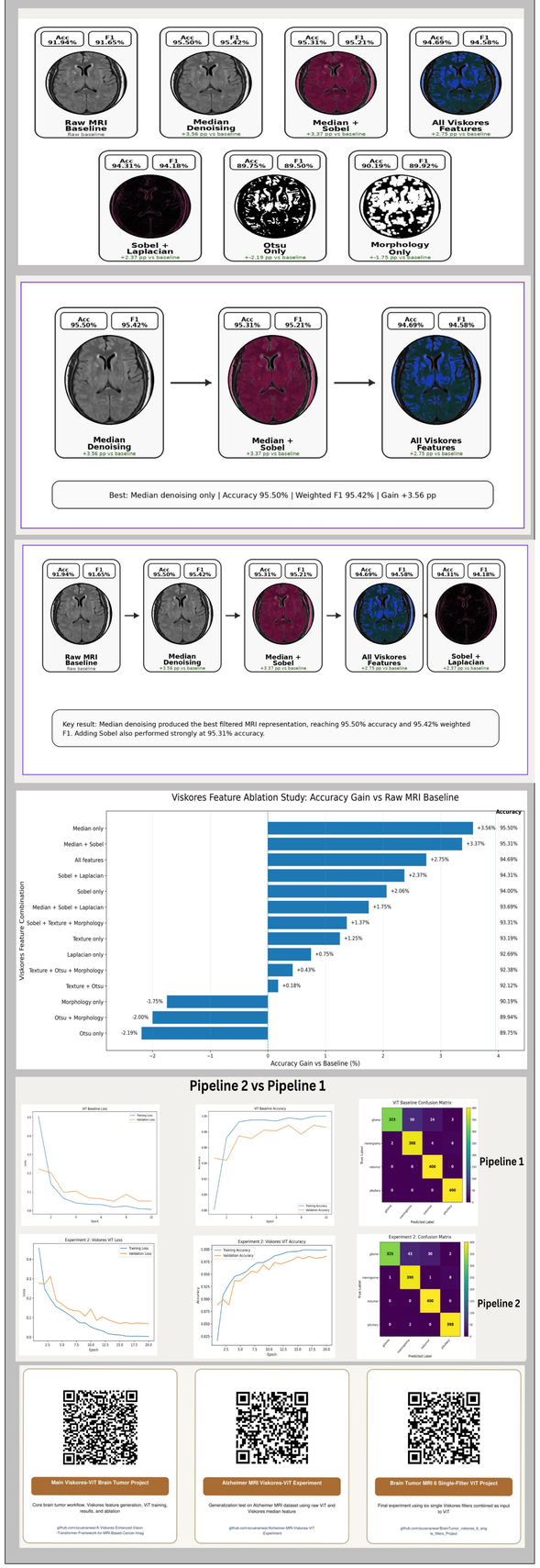




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1. A. Dosovitskiy et al., “An Image Is Worth 16×16 Words: Transformers for Image Recognition at Scale,” *ICLR*, 2021.
2. K. Moreland et al., “Viskores: Integrating Parallel Scientific Visualization Research into Applications,” *VisGap*, 2026.
3. https://www.kaggle.com/code/yousefmohamed20/brain-tumor-mri-accuracy-99/input

RESULTS



DISCUSSION

- The raw MRI ViT baseline achieved 91.94% accuracy and 91.65% weighted F1-score.
- The Viskores-enhanced fused-feature pipeline improved performance to **94.56% accuracy** and **94.43% weighted F1-score**.
- The ablation study showed that feature selection strongly influences classification performance.
- Median denoising achieved the best overall result (**95.50% accuracy**), a **3.56 percentage-point improvement** over the raw baseline.
- Median + Sobel also performed strongly, highlighting the value of denoising and edge-preserving features.
- Overall, the findings support the hypothesis that Viskores-derived scientific features can enhance ViT-based MRI classification.

CONCLUSION

This work demonstrates that **integrating Viskores-generated features with a Vision Transformer has the potential to improve MRI-based brain tumor classification** by enhancing important image characteristics that are often missed in raw MRI images. Leveraging Frontier’s high-performance computing enables efficient model training and evaluation, providing a foundation for more accurate and scalable AI solutions in medical imaging.

FUTURE WORK

- Validate the workflow on additional MRI datasets to assess generalization.
- Extend the framework to 3D and multimodal MRI.
- Revisit Viskores rendering-based features using improved rendering, smoothing, and surface/volume strategies to address the faceted outputs observed in this study.
- Explore optimal feature combinations for improved ViT classification.

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