

Brain Tumor Classification



Section 1

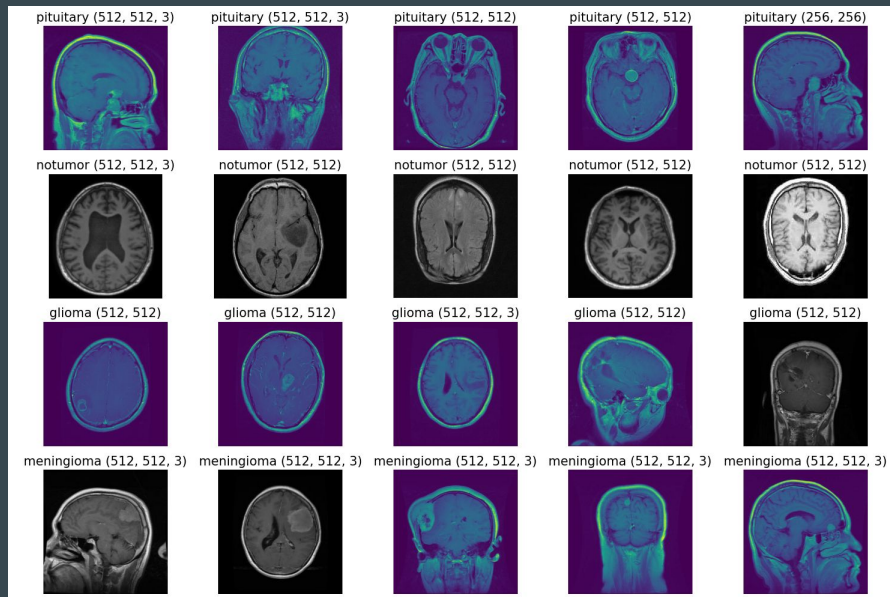
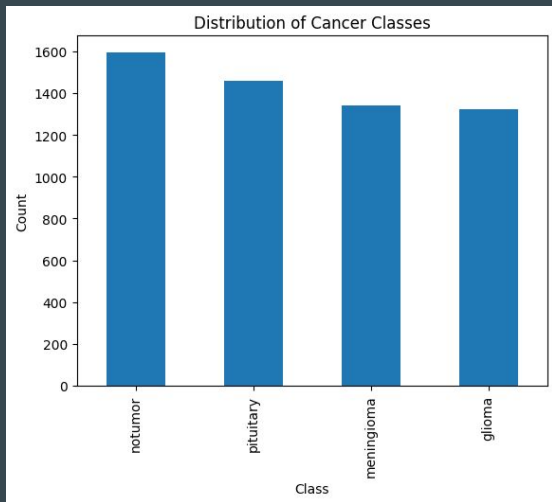
Tuesday, August 5, 2025

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https://github.com/Richard-Yan-UCB/datasci281_final_project

Dataset

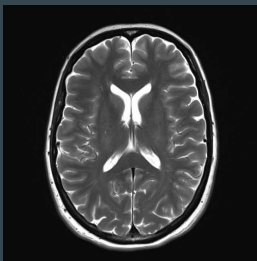
- Goal
 - Classify MRI brain scans into 4 classes: meningioma, pituitary, glioma, notumor
- Dataset Size:
 - Train: 5712 images (~1300-1600 per class)
 - Test: 1311 images



<https://www.kaggle.com/datasets/masoudnickparvar/brain-tumor-mri-dataset/data>

Image Pre-Processing

- Image Noise Factors
 - Inverted grayscale (GSI)
 - Text/watermarks in some MRIs
 - Aliasing due to JPEG compression
 - Different POVs in the MRIs: axial, sagittal, coronal
 - Different sequence types
 - Different brightness intensities
 - Different Image Sizes/Resolutions



Tr-no_0029 (GSI)



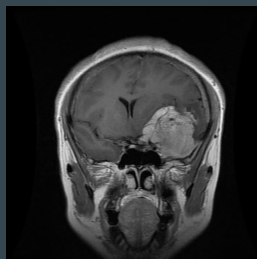
Tr-no_0424
(text/watermark)



Tr-no_0448 (aliasing
+ text/watermark)



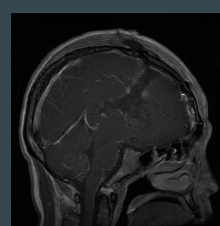
Tr-no_0230 (ADC
sequence)



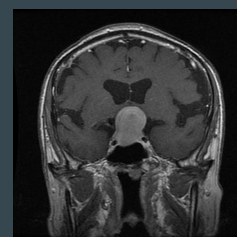
Tr-me_0017 (T1
sequence)



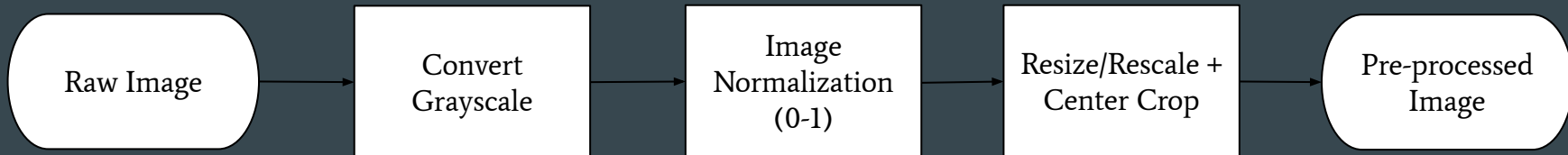
Tr-no_0122 (high
contrast & too
bright)



Tr-gl_1051 (low
contrast & too
dark)

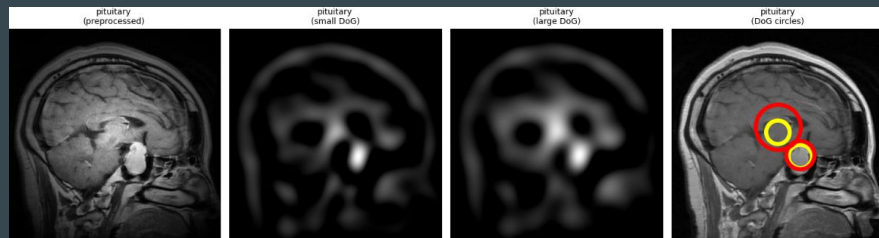


Tr-pi_0289
(normal
brightness/contrast)

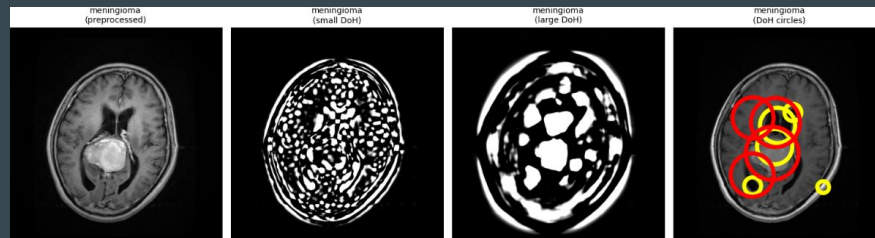


Features

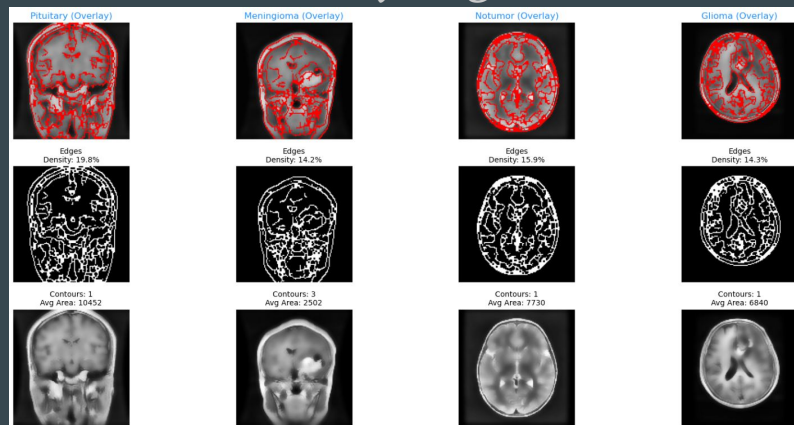
Difference of Gaussians



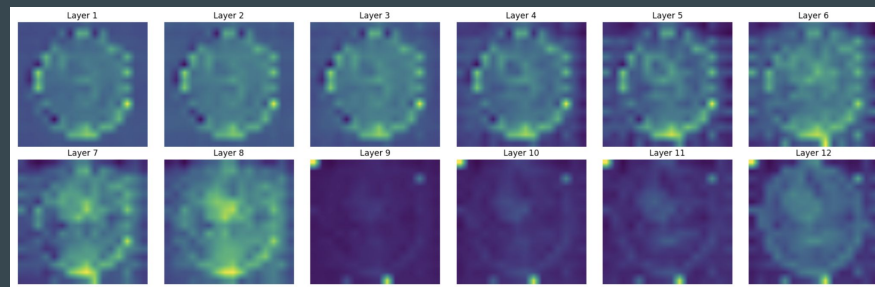
Determinant of Hessians



Canny Edges

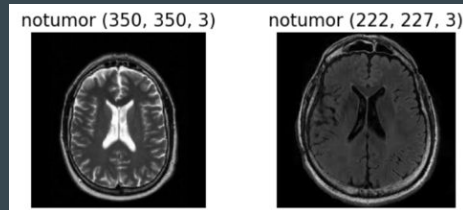
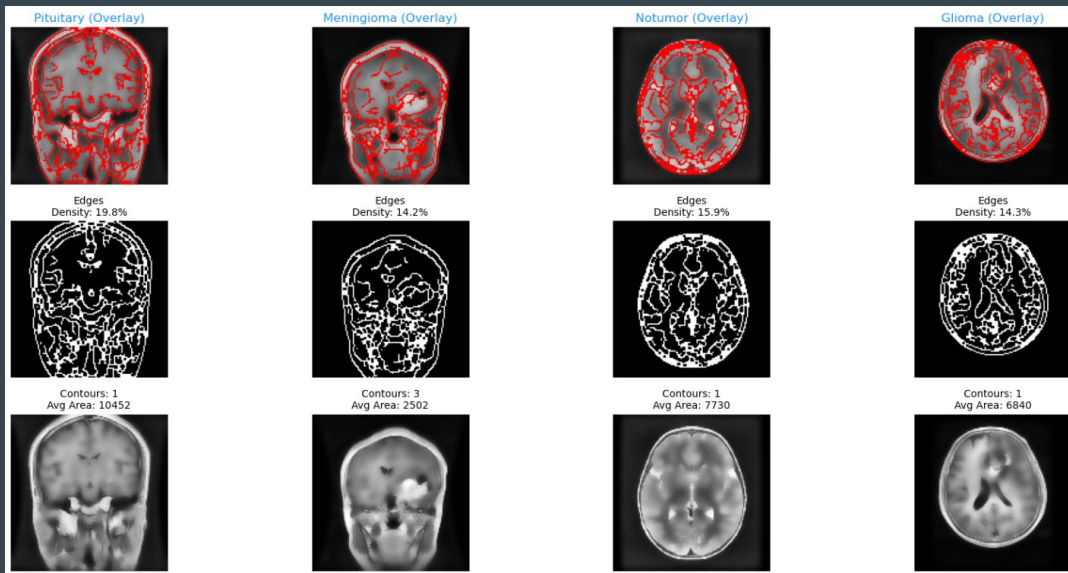


Complex

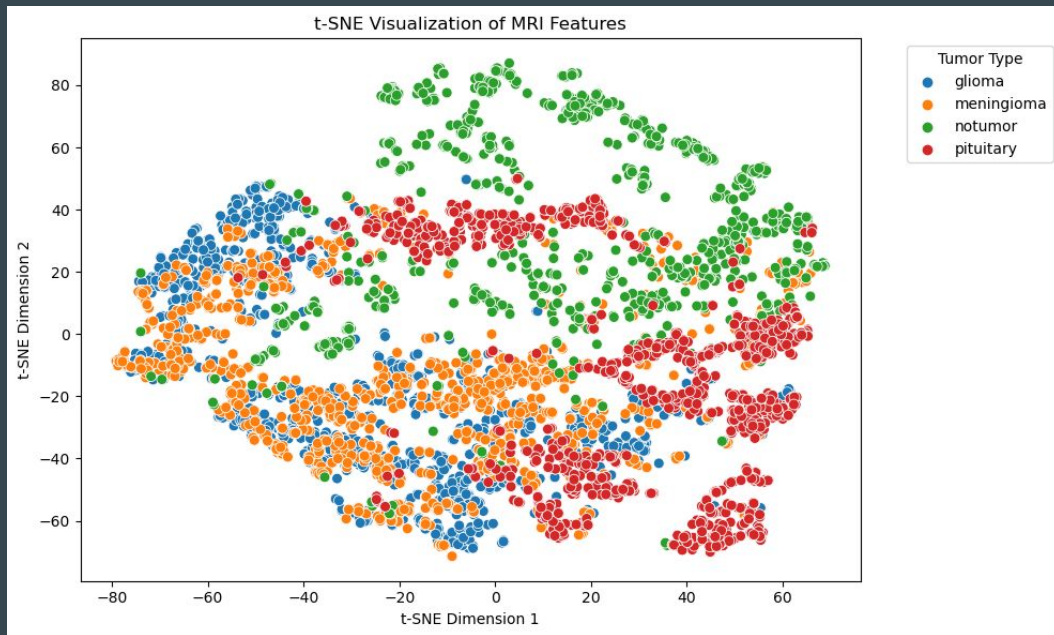


Canny Edges

- Some tumors produce smoother, well-circumscribed edges. This might be helpful in informing what type of tumor it is when used within a classifier.
- Some images are grayscale inverted. Canny edges only highlights edges/contrast differences from pixel to pixel. This helps to reconcile some images being grayscale and others being grayscale inverted.



Canny Edges



- t-SNE applied to Canny edge features to showcasing strong separability between pituitary and notumor classes.
- Some overlap between glioma and meningioma - suggesting similar visual structures.

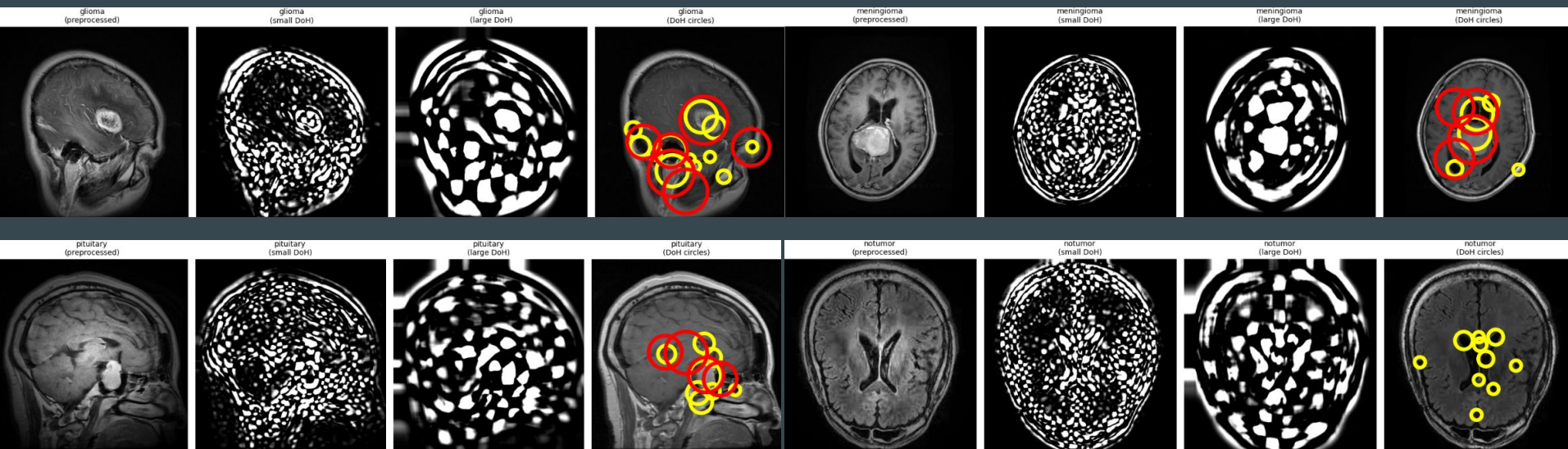
Difference of Gaussians

- DoG takes the difference of two gaussian-blurred versions of the image with increasing standard deviations (sigmas), emphasizing the high-frequency signals. Differences are taken for a range of sigmas and stacked in a cube. Blobs are local maximas in cube and can be thresholded.
- Works for bright on dark blobs
- Preprocessing: CLAHE (contrast limited adaptive histogram equalization) + vignette for skull stripping



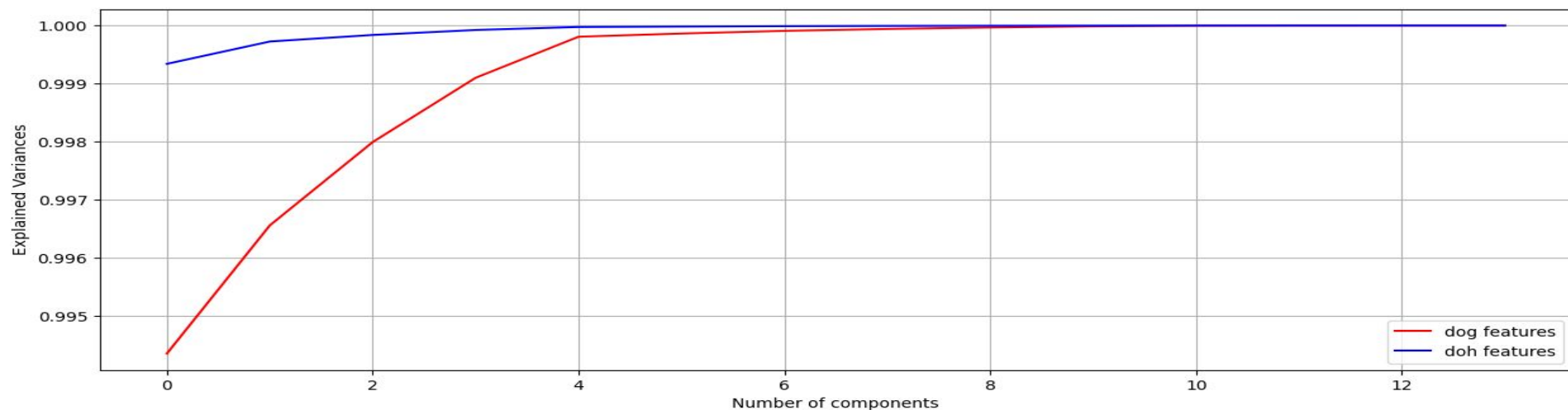
Determinant of Hessians

- DoH calculates the matrix of the Determinant of Hessian using Gaussian kernels with a range of standard deviations (sigma). Hessian matrix represents local curvature at each point. Blobs are the local maximas in the Hessian matrix.
- Works for bright on dark and dark on bright blobs (e.g. gliomas)
- Preprocessing: CLAHE (contrast limited adaptive histogram equalization) + vignette for skull stripping



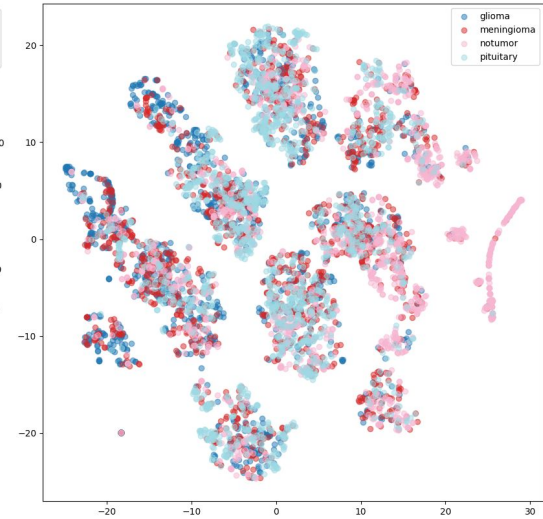
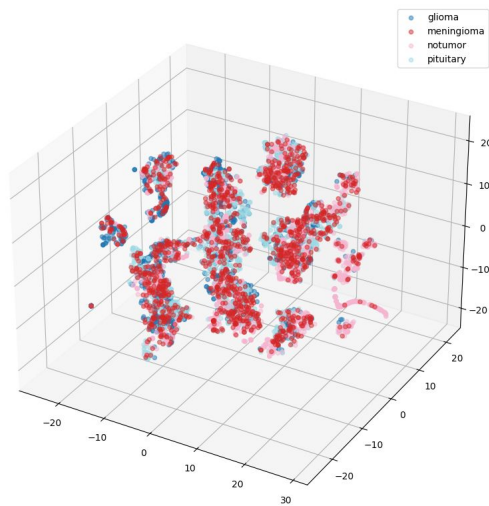
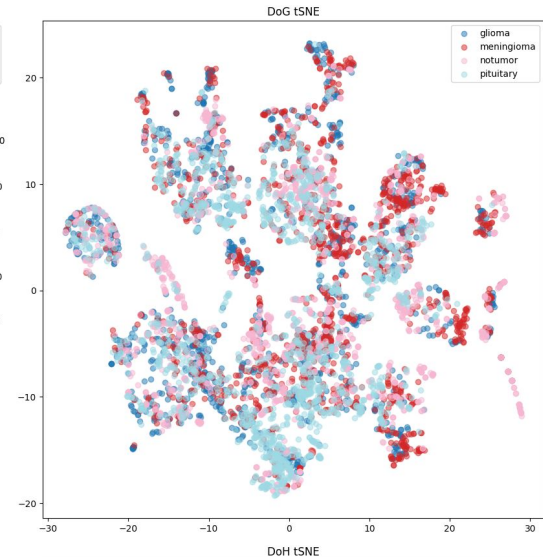
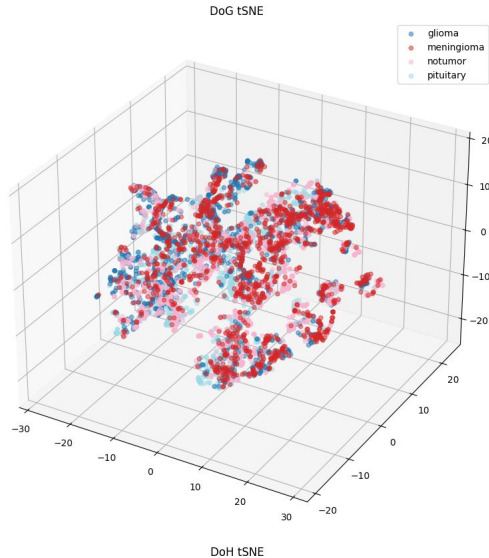
DoG & DoH PCA

- Features are 14-length vectors of stats: [# blobs, blob density, avg y, stdev y, min y, max y, avg x, stdev x, min x, max x, avg radius, stdev r, min r, max r], where x, y and r are normalized x, y, and radius of blobs.
- PCA explained variance plot shows that dimensions besides the 1st principal component are not too useful in explaining more of the total variance

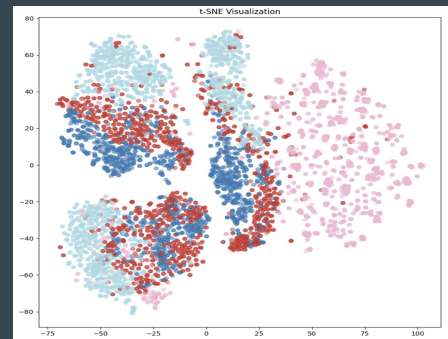
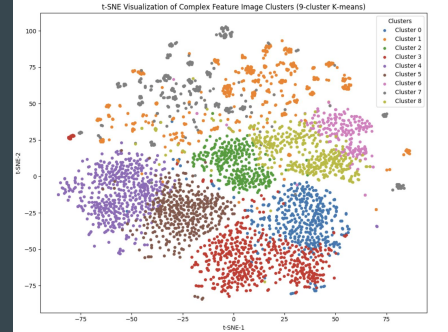
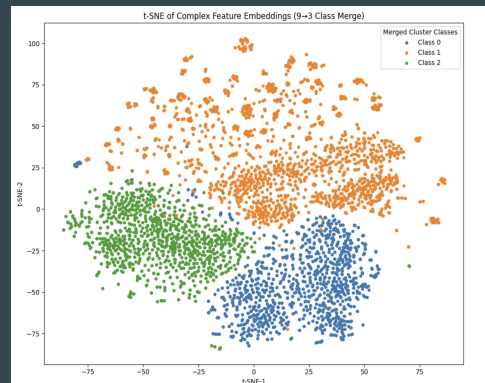
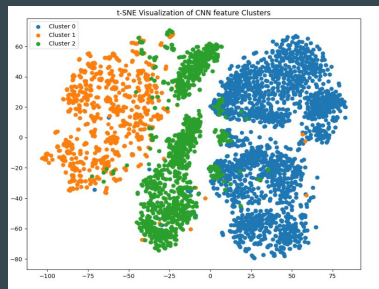
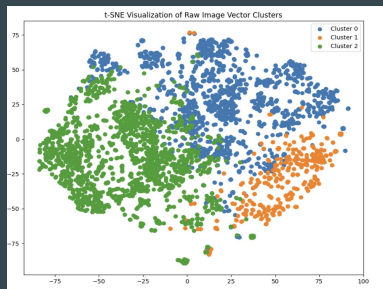


DoG & DoH t-SNE

- Lots of overlap, subtle separation
- DoG
 - Pituitary pulled left, front
 - Glioma similar
 - Notumor slightly lower (?)
 - Meningioma pulled right, back, and slightly higher
- DoH
 - Pituitary pulled left middle
 - Glioma pulled left, back
 - Notumor pulled right
 - Meningioma similar to glioma but higher



Complex Features

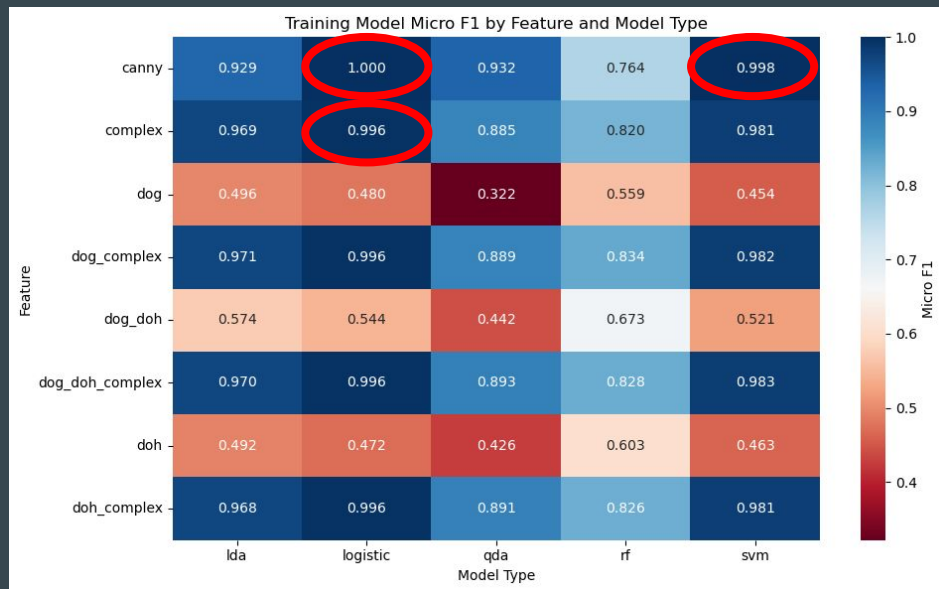


Dimensionality Reduction Strategy

- DoH + DoG
 - Summarize the blobs into 14 components
 - Number of Blobs
 - Blob Density (Number of Blobs/Image Area)
 - Mean X, Y, Radius
 - Standard Deviation X, Y, Radius
 - Max X, Y, Radius
 - Minimum X, Y, Radius
- Canny Edges
 - PCA to 1000 Components from 262,144
- Complex
 - Used CLS token to summarize to 768 components

Training Results

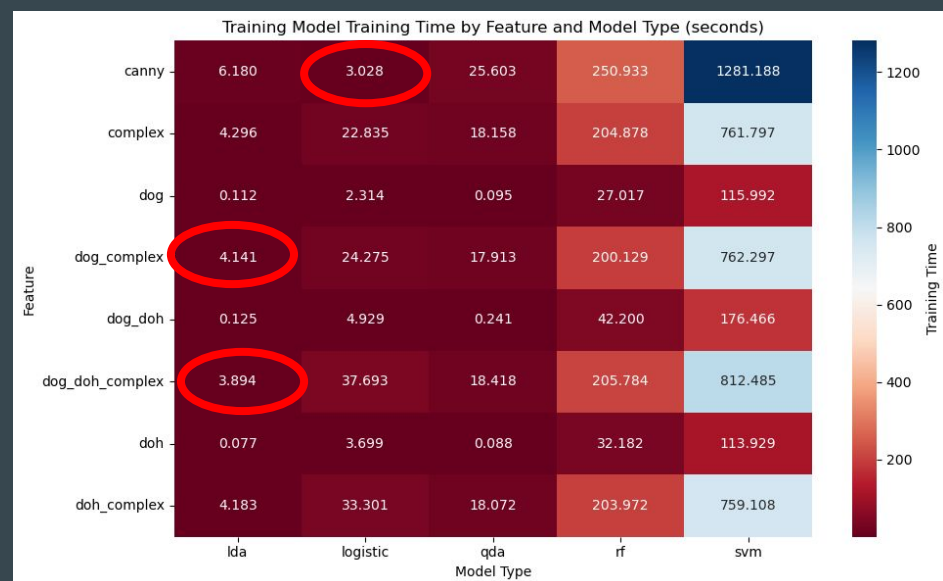
Accuracy



Top 3 Accuracy:

1. Logistic + Canny - 100%
2. SVM + Canny - 99.8%
3. Logistic + Complex - 99.6%

Training Time

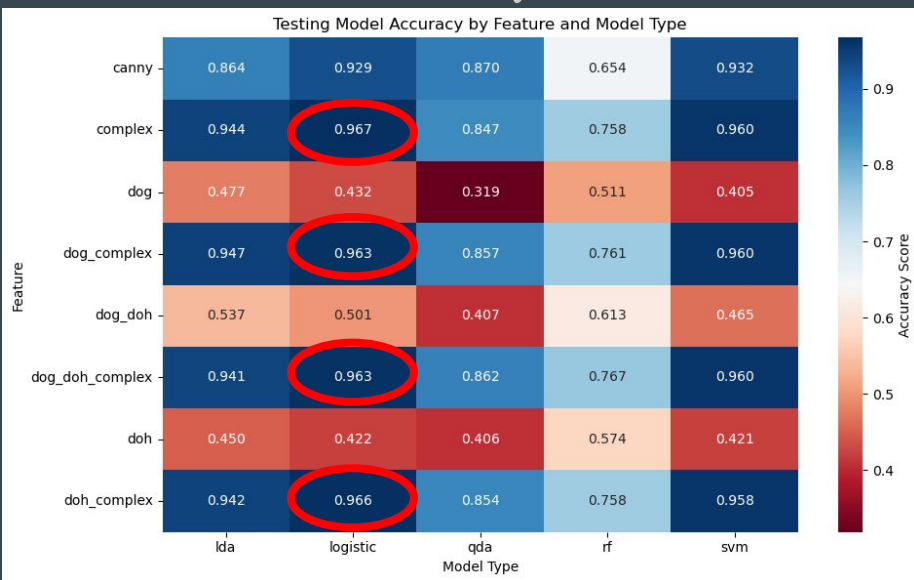


Top 3 Training Time (>90% accuracy):

1. Logistic + Canny - 3.028 seconds
2. DoG/DoH/Complex +LDA - 3.894 seconds
3. DoG/Complex + LDA - 4.141 seconds

Testing Results

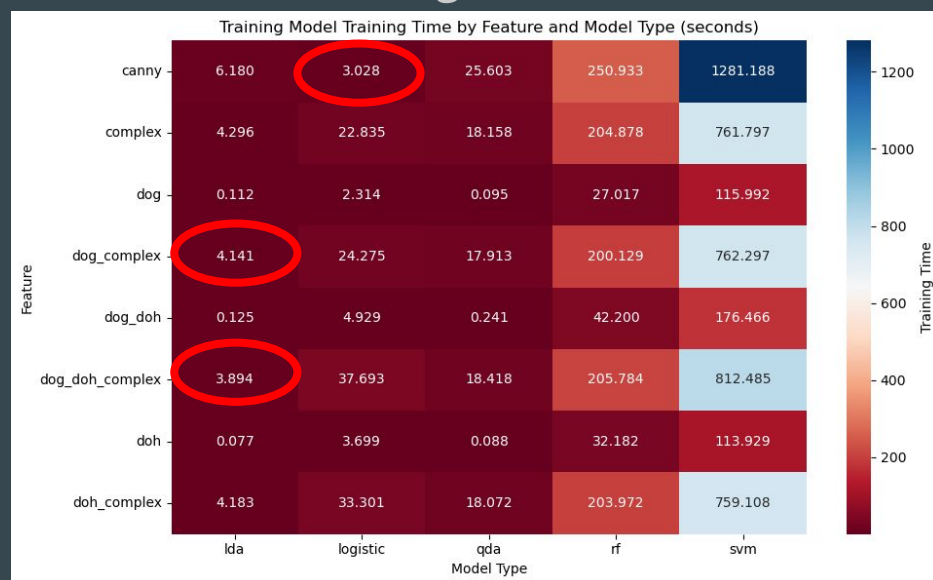
Accuracy



Top 3 Accuracy:

1. Logistic + Complex - 96.7%
2. Logistic + DoH/Complex - 96.6%
3. Logistic + DoG/Complex - 96.3%

Training Time

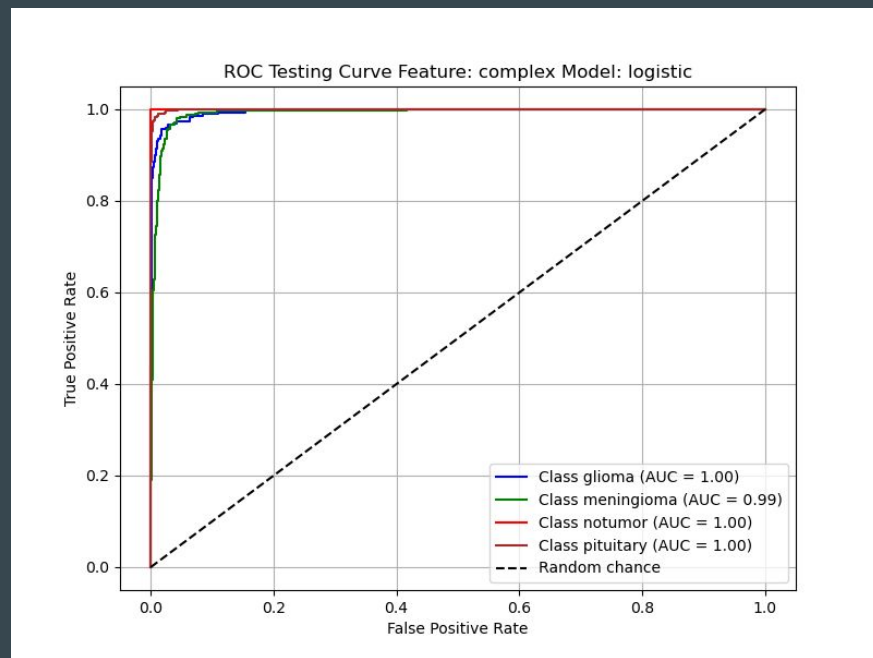
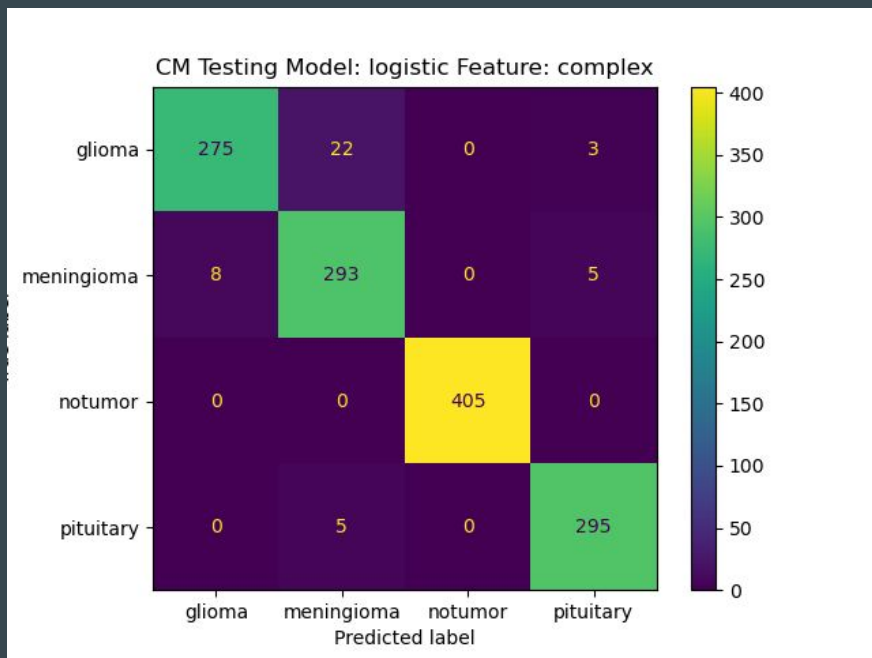


Top 3 Training Time (>90% accuracy):

1. Logistic + Canny - 3.028 seconds
2. LDA + DoG/DoH/Complex - 3.894 seconds
3. LDA + DoG/Complex - 4.141 seconds

Best Model ROC + Confusion Matrix (Testing)

- Complex + Logistic Regression proved to be the best combination of feature + model type for generalization



Lessons Learned

- Not all image classification tasks require a deep CNN to achieve relatively good performance (>90%).
- Dimensionality reduction strategies can drastically improve model training time.
- Image standardization and preprocessing is 80% of the work. Model training is easy after images are preprocessed.

Thank You!