Vector Quantized Variational Autoencoder

Winter 2025

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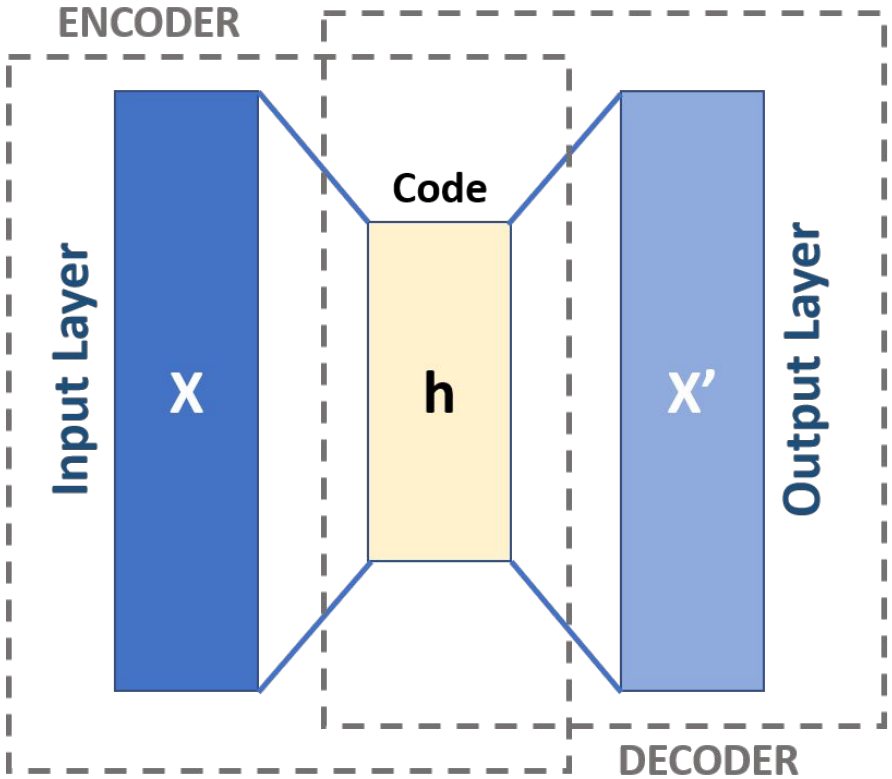
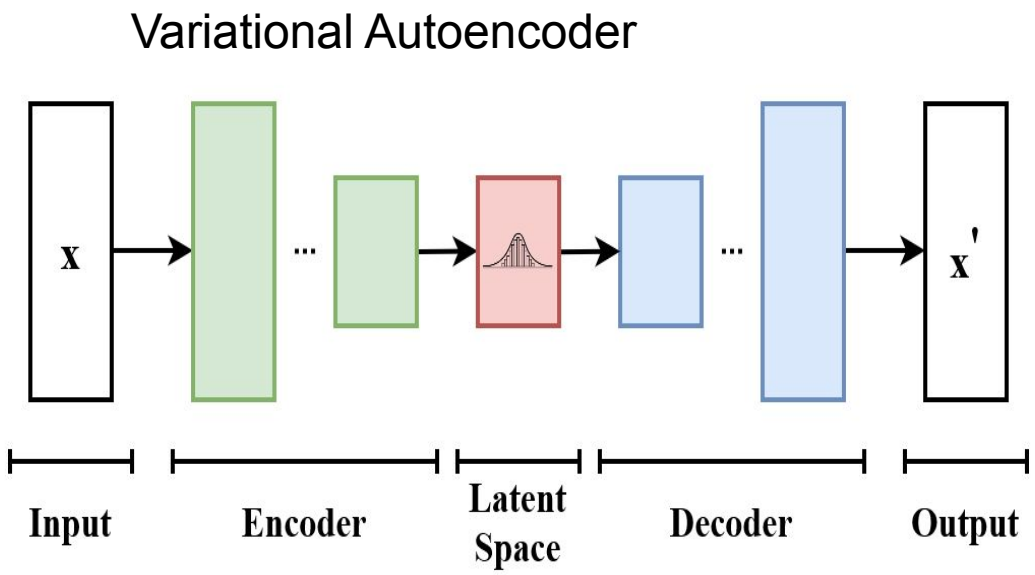
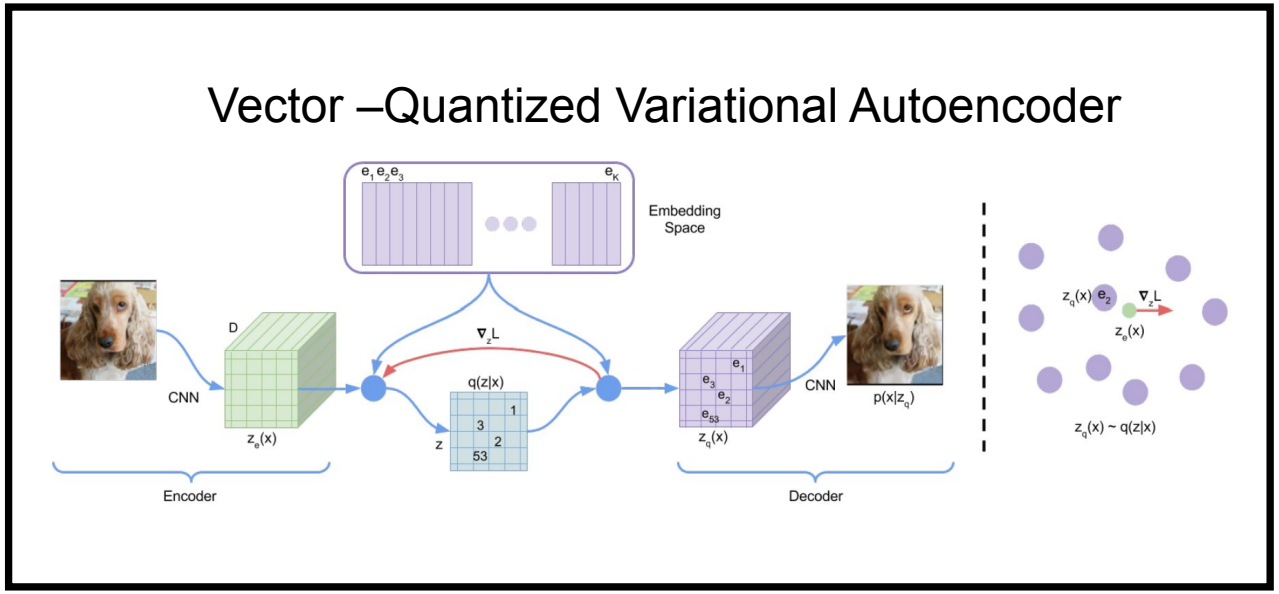
What are autoencoders?

- Autoencoders are a type of artificial neural network (ANN) that compress and reconstruct data. They are an unsupervised machine learning (ANN) that can learn powerful statistics from any dataset.



Different types of autoencoders

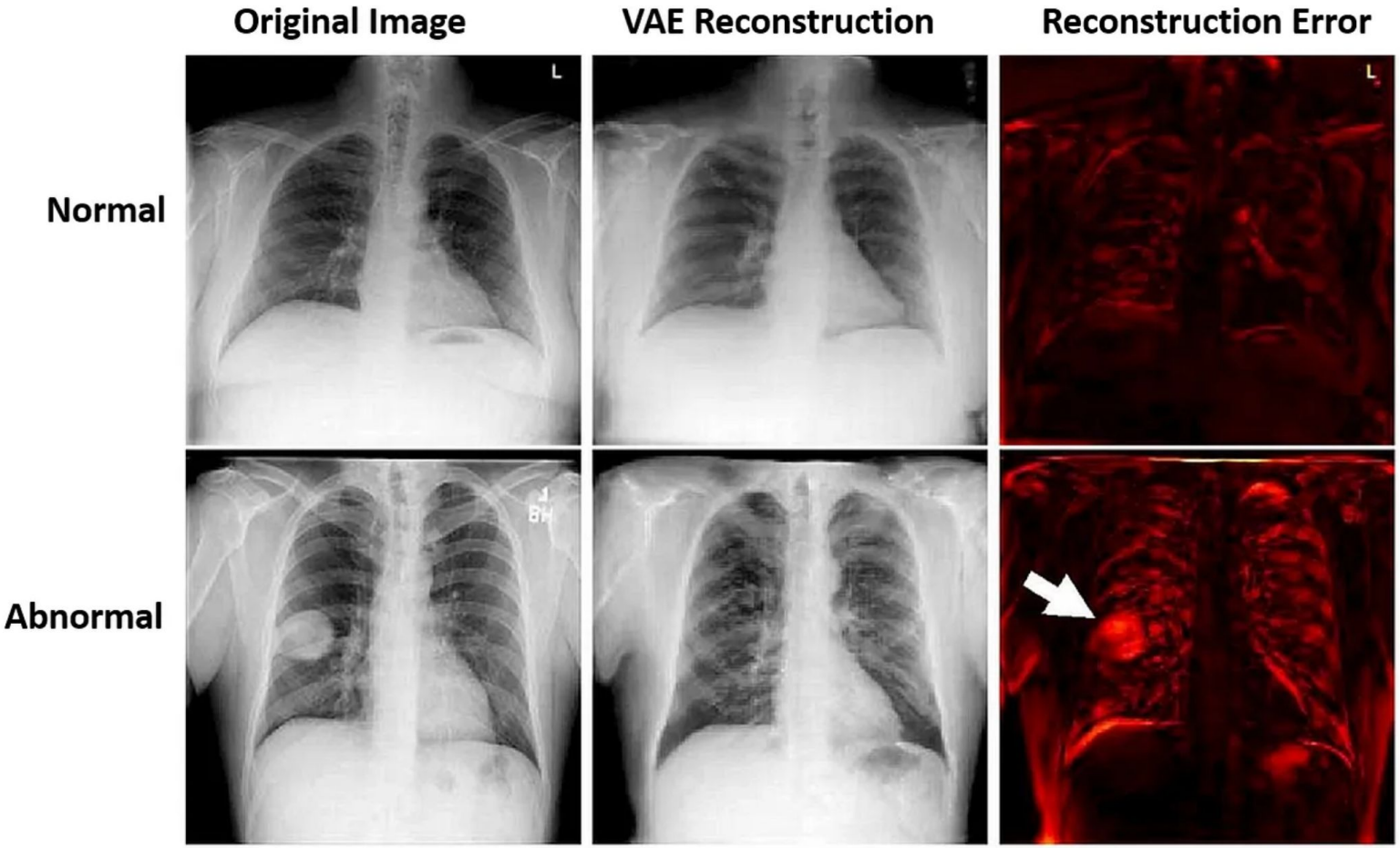




What are autoencoders used for?

- **Data compression**: Autoencoders can compress data to make it easier to store and transmit.
- **Image denoising**: Autoencoders can remove noise from images.
- **Anomaly detection**: Autoencoders can identify unusual activity in data, such as in financial markets.
- **Feature learning**: Autoencoders can extract important features from data, which can be used in computer vision, natural language processing, and more.
- **Image inpainting**: Autoencoders can fill in missing pixels in images.
- **Information retrieval**: Autoencoders can help users search for images based on their content.

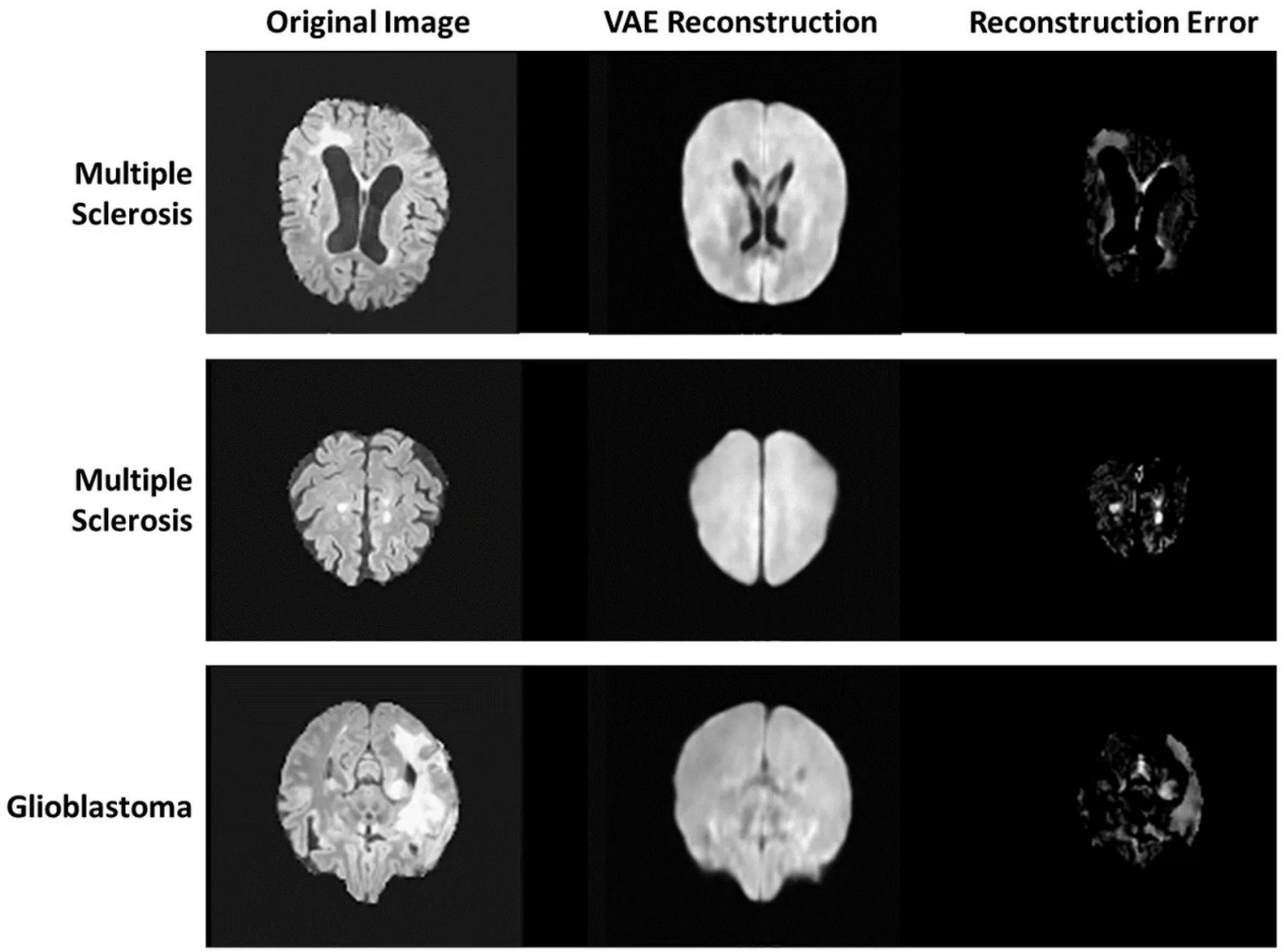
Autoencoders in anomaly detection



Anomaly detection on chest radiograph, with a lung mass on the abnormal image

Demeusy, 2024

Autoencoders in anomaly detection

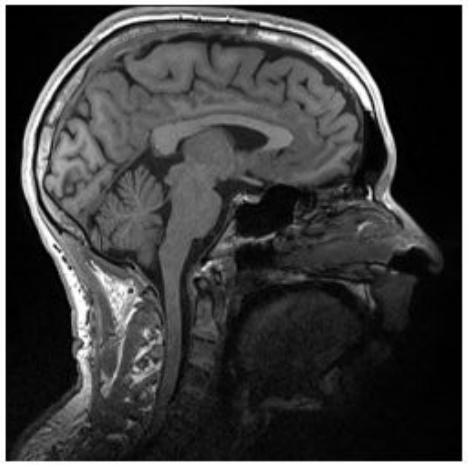


MRI, VAE reconstruction and error reconstruction

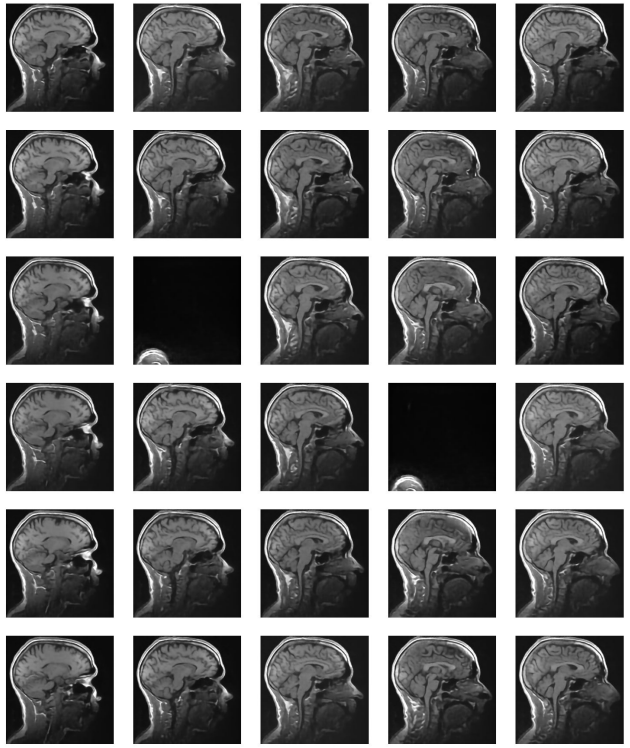
Demeusy, 2024

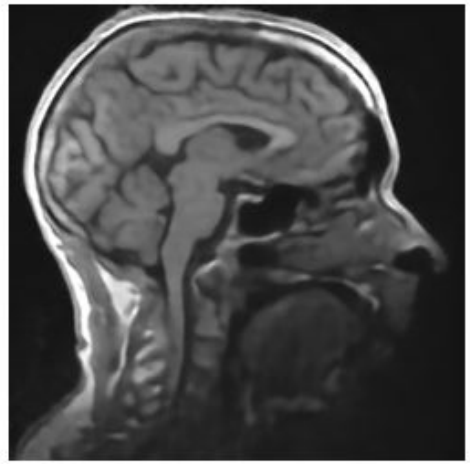
Indiv Dataset

- Used IXI_Dataset:
  - Nearly 600 MR images from normal, healthy subjects
  - T1 images
- Converted the 3D scans to **76,800** 2D slices
- Trained a VQVAE model on the slices
- It successfully reconstructed the unseen individuals from Indiv's:



Indiv's T1 scans





VQVAE reconstructions

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Quick Test!

Binary Classifier: Cats vs Dogs

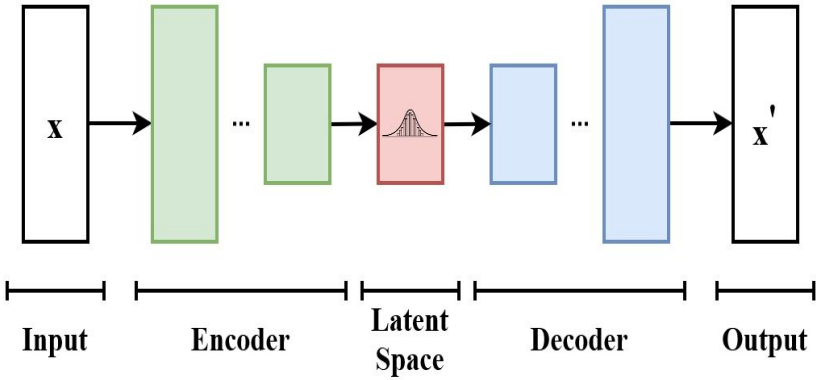
Large training dataset for VQVAE (5k?)

Test set for VQVAE & Train for cats vs dogs classifier (100)

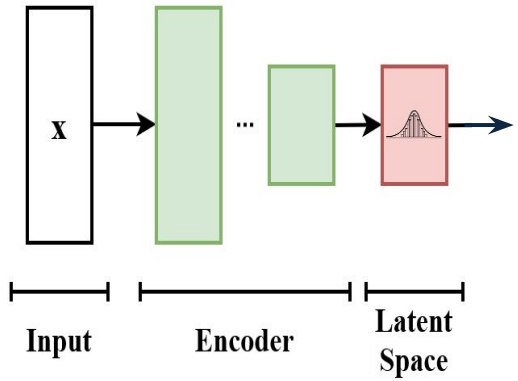
Test set for cats vs dogs classifier (N=15000)

Train a vqvae on large cats and dogs dataset

(analogous to IXI T1 dataset)

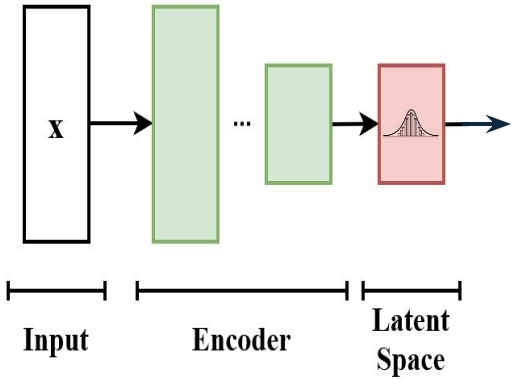


(IndivRobotics)



Save quantized output to numpy file

1)



Save quantized output to numpy file (e.g. 002_cat.npy)

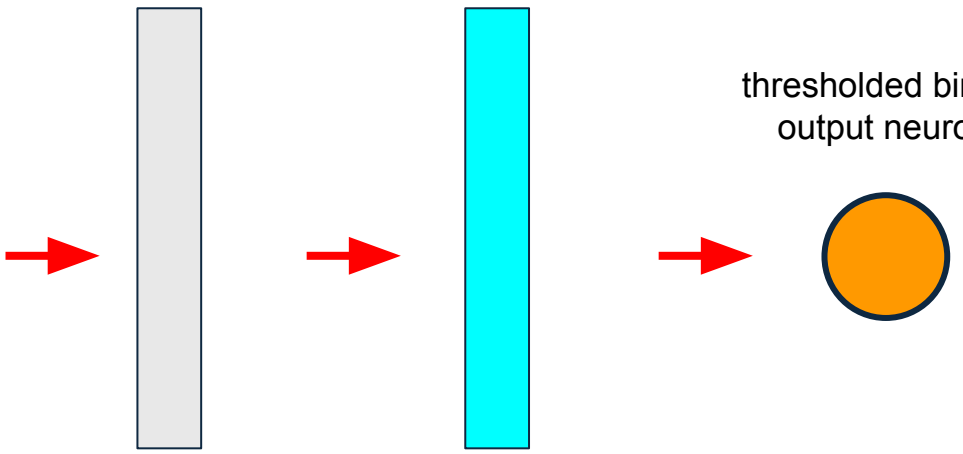
frozen weights

learnable weights

2)

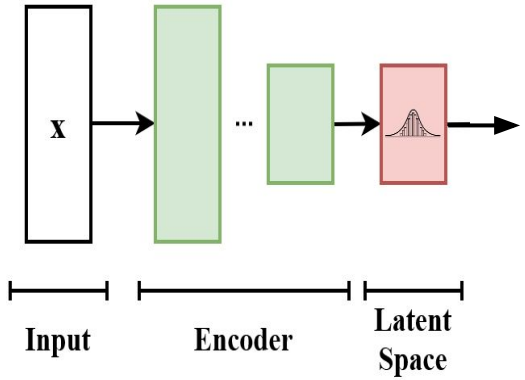
Frozen Weights

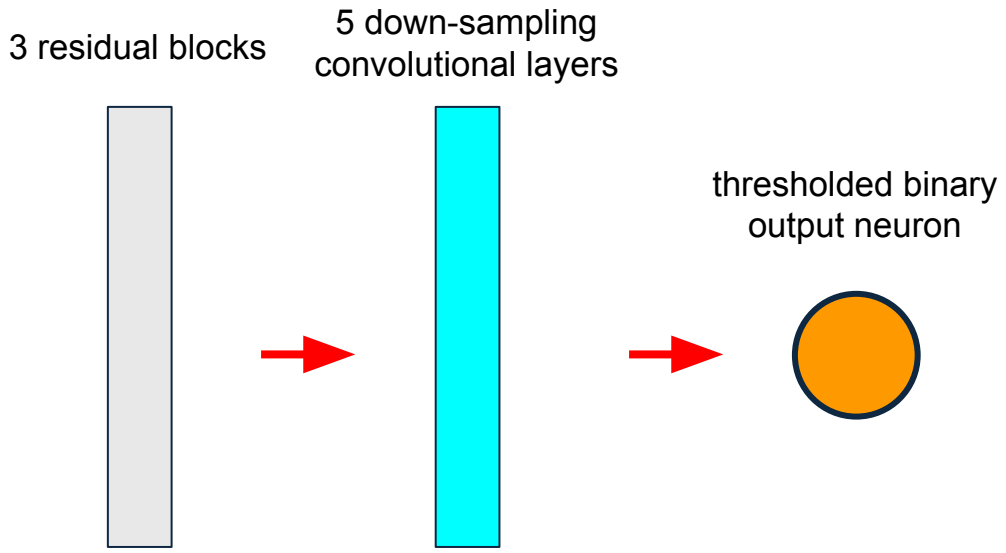
Load numpy file in a different script



Viable alternative (all-in-one script)

1)





frozen weights

learnable weights

Quick Theory Test

Binary Classifier:
Cats vs Dogs

Analogous to Indiv's (test)

Analogous to large IXI dataset (train)

What I've done!

- Used IXI_Dataset:
  - Nearly 600 MR images from normal, healthy subjects
  - T1 images
- Converted the images to **RAS (Right-Anterior-Superior) coordinate system**, which is a standard convention for neuroimaging data
- Converted the 3D scans to 2D slices (each person has 128 slices, giving us 76,800 total)
- Normalized the images using maximum voxel intensity for each subject
- Trained the VQVAE with the 2D images
- The images were successfully reconstructed by the network
- In training: 3 downsampling layers (stride=2) – 8 times smaller (256*256 turned into 32*32 in the encoder) – 128 slices per subject
- In testing: 3 downsampling layers (stride=2) – 8 times smaller (320*320 turned into 40*40 in the encoder) – 240 slices per subject