

## Learning to Generate: A Quarter Exploring Generative Models

Mentee: Jennifer Zhang

Mentor: Yuhan Qian

This quarter, under the mentorship of Yuhan Qian, I explored the theoretical foundations and practical applications of three cornerstone generative models in modern machine learning: Variational Autoencoders (VAEs), Generative Adversarial Networks (GANs), and Diffusion Models.

We began by studying the Variational Autoencoder, a latent variable model that combines deep learning with probabilistic inference. I learned how VAEs encode input data into a latent space, and how the loss function balances reconstruction error and KL divergence to encourage smooth and continuous latent distributions. I implemented a VAE in PyTorch and trained it to generate images resembling the digit '1' from the MNIST dataset, gaining practical experience with encoder-decoder architectures and conditional generation.

Next, we moved on to GANs, where I studied the adversarial training paradigm involving a generator and a discriminator. I explored stability issues in GAN training and examined techniques such as label smoothing and Wasserstein loss. Comparing GANs with VAEs deepened my understanding of the trade-offs between sample quality and latent space structure.

Finally, I investigated Diffusion Models, a rapidly emerging class of generative models that learn to reverse a Markovian noising process. Through reading papers such as *DDPM* and *Stable Diffusion*, I understood how these models achieve state-of-the-art performance in image generation by optimizing likelihood-based objectives across multiple noise steps.

Throughout the quarter, I developed both theoretical insight and practical coding skills in the domain of generative models. My mentor provided insightful guidance on interpreting research papers, debugging implementations, and thinking critically about design choices in generative architectures.

This DRP experience solidified my interest in generative modeling and gave me a strong foundation for future work in deep learning and AI research.