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1. Reparametrization trick: Explain how the trick works and what problem it addresses.

- In VAE we need to sample the latent variable z from a distribution N(μ, σ). The problem is that the sampling operation is random and no gradient is defined, which prevents backpropagation
- The reparametrization trick bypasses the randomness by expressing the sampling operation deterministic with 2 parts.
    1. The random part by sampling ε from a standard normal distribution N(0, 1)
    2. The deterministic part μ and σ (parameters to learn)
- Then the computation of $z = \mu + \varepsilon * \sigma$ is deterministic and allows backpropagation of z through μ and σ

2. Explain in your own words why optimization is hard in the case of GANs. What are common ways to improve GAN training stability?

- Optimization of GAN is hard because the optimization happens in a minimax game format with the generator and discriminator, they need to be equally good to properly train
- Vanishing gradient: If the discriminator is too good, then the gradient signal for updating is very small and leads to slow or no progress in improving the generator
    - Solution: The generator is especially bad at the beginning, so let learn alone a little to get better. Additionally, adjust the loss of the generator with a minus sign then gradient signal is larger if the discriminator is too good
- Mode collapse: The generator "collapses" into generating only a few modes (classes or patterns) and produces repetitive outputs. It fails to capture the diversity of the true data distribution.
    - Solution: Wasserstein GAN, not further discussed in lecture

3. Shortly compare GANs and VAEs. In which setting would you select one over the other?

- Structure
    - GAN consists of a generator and a discriminator playing a minimax game where the generator produces fake data and the discriminator has to distinguish between real and fake data
    - VAE consists of an encoder, mapping the data to a latent space and the decoder reconstructs the data from the latent space
- Sampling
    - Both sample from a latent space to generate new data, with the generator doing this in GAN and the decoder in VAE
- Latent Space Distribution
    - GAN assumes standard normal distribution N(0, 1) and VAE assumes N(μ, σ) and tries to approximate real distribution
- Training objective
    - GAN minimizes the classification error in a minimax game and VAE maximizes ELBO and minimizes reconstruction error

- Output Quality
    - GANs often produce more realistic images and VAE tends to create blurrier images due to smoothing the latent space
- Application
    - GAN: Realistic image generation
    - VAE: Understanding the latent space for tasks like data reconstruction or anomaly detection