TTIC 31230, Fundamentals of Deep Learning

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Progressive VAEs

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These slides on progressive VAES were written"gedanken" (as a thought experiment) while teaching deep learning in 2021.

The original motivation for progressive VAEs was to provide a theoretically clean approach to a multi-layer VQ-VAEs.

However, this formulation of progressive VAEs will be useful in understanding diffusion models (currently very popular).

Progressive VAEs

We consider a VAE with layers of latent variables $z_1, \ldots, z_L$ and a population distribution on an observable variable y.

The encoder will define $P_{\text{enc}}(z_1|y)$ and $P_{\text{enc}}(z_{\ell+1}|z_\ell)$.

The decoder will define $P_{\text{dec}}(z_{\ell-1}|z_\ell)$ and $P_{\text{dec}}(y|z_1)$.

Following VQ-VAE, we will train the encoder and the decoder independent of any prior.

We then train a prior on the top layer latent variable. The top level prior and decoder allow us to sample y from the model.

Phase One Training

We train a encoders and decoders $\text{enc}_1, \text{dec}_1, \ldots, \text{enc}_L, \text{dec}_L$ where the distribution on $z_1, \ldots, Z_L$ is defined by y and the encoder.

$$\text{enc}_1^*, \text{dec}_1^* = \underset{\text{enc}_1, \text{dec}_1}{\text{argmin}} \; E_{y, z_1} \left[-\ln P_{\text{dec}_1}(y | z_1) \right]$$

$$\text{enc}_{\ell+1}^*, \text{dec}_{\ell+1}^* = \underset{\text{enc}_{\ell+1}, \text{dec}_{\ell+1}}{\text{argmin}} \; E_{z_\ell, z_{\ell+1}} \left[-\ln P_{\text{dec}_{\ell+1}}(z_{\ell-1} | z_\ell) \right]$$

If these encoders and decoders share parameters the shared parameters are influenced by all of the above training losses (this observation was added after seeing DALLE-2's diffision model).

Phase Two Training

$$\text{pri}^* = \underset{\text{pri}}{\text{argmin}} \; E_{z_L}\left[-\ln P_{\text{pri}}(z_L)\right]$$

Because of the autonomy of the encoder, the universality assumption implies that we get a perfect model of the population distribution on y.

Given the prior and the decoder we can sample images.

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