Deep Learning **Summer Term 2024**

`http://ml3.leuphana.de/lectures/summer24/DL`
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Exercise 7

Due on: Thursday, 27.06.2024

Task 17 Denoising Autoencoder

(Due on: 20.06.2024)

In this task we want to extend our previous autoencoder to a denoising autoencoder.

Test various corruptions on your input. We already know how to add random Gaussian noise. There are also `GaussianBlur` and `RandomErasing` transforms you might want to try.

Hint: Remember that you need the corrupted and the original input during training. Hence, think about where to apply the corruption!

Task 18 A First Generative Model

Turn your autoencoder into a generative model. For simplification, assume that your latent space is distributed according to a Gaussian. Estimate the parameters of that Gaussian, sample from that distribution, and decode the samples using your decoder. Visualize the generated images.

Task 19 Variational Autoencoder

This task is about implementing and testing a variational autoencoder (VAE). We assume that our encoder models $q_\phi(z|x)$ via a Gaussian that has a mean $\mu \in \mathbb{R}^d$ and a diagonal covariance matrix $\sigma_1, \ldots, \sigma_d \in \mathbb{R}_{>0}$, where d denotes the dimensionality of the latent space. Hence, the output of the encoder is $2d$-dimensional. The loss function, as depicted in slide 12 of `lecture9.pdf`, is given by

$$\mathcal{L}_{\theta,\phi} = \underbrace{\mathbb{E}_{q_\phi(z|x)}\left[\log p_\theta(x|z)\right]}_{\text{reconstruction error}} - \underbrace{D_{\mathrm{KL}}(q_\phi(z|x) \| p_\theta(z))}_{\text{latent space matches prior?}} ,$$

where the first term is the binary cross entropy loss and the second term measures the alignment of the latent space with the pre-defined prior. We use a standard Gaussian as a prior. Hence, the KL-term is given by $\frac{1}{2}\left(\sum_{j=1}^{d} \sigma_j^2 + \mu_j^2 - 1 - \ln \sigma_j^2\right)$ as derived in Exercise 6.

(i) Train a VAE on Fashion-MNIST using a two-dimensional latent space.

(ii) Visualize the latent-space and color the data points according to their label. Does the latent space look like a standard Gaussian?

(iii) Sample from the prior distribution and decode the samples using your decoder. Visualize the generated images from your generative model.

Hint: Instead of modelling σ_j, model $\log \sigma_j$. Hence, you do not have to take care of the non-negativity. Read the first chapter of *An Introduction to Variational Autoencoders* (`https://arxiv.org/abs/1906.02691`, click on pdf on the right-hand side).

Task 20 Bonus: BatchNorm

Read Section 8.7.1 of the Deep Learning Book (`http://www.deeplearningbook.org/`) to understand the necessity of having the parameters β and γ in the BatchNorm layer.