Deep Learning Labsheet 07

IT21197246

Abeykoon A.M.Y.V.B

**Question 2)** When above AE is used without activation functions, it is called a linear AE. Explain the relationship between linear AE and principal component analysis (PCA). Write the answer in a word file.

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When an Autoencoder (AE) is used without activation functions, it becomes a linear AE. In this case, the AE behaves similarly to Principal Component Analysis (PCA). Both methods aim to reduce the dimensionality of the input data while retaining as much of the original data's variance as possible. PCA achieves this by finding the principal components,   
which are the directions in which the data varies the most. These components are orthogonal and ranked according to the amount of variance they capture. Linear AEs, on the other hand, also learn a lower-dimensional representation by minimizing the reconstruction error, similar to PCA. In fact, it has been shown that, under certain conditions, a linear AE can learn the same subspace as PCA. Both methods seek to approximate the original data in a lower-dimensional space, but AEs have the flexibility to be extended with non-linear activation functions, making them more powerful and   
versatile for complex datasets. However, in the linear case, both methods are mathematically equivalent and produce similar results.

**Question 6)** Observe the model performance improvements between the Image De-noising AE and the Vanilla CNN AE. Explain the reason for this observation.

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The Image Denoising Autoencoder (AE) performs better than the Vanilla CNN Autoencoder (AE) because it is specifically designed to handle noisy images, whereas the Vanilla CNN AE is only focused on reconstructing images without dealing with any added noise.

In the Image Denoising AE, the model learns to remove the noise from images, which forces it to pick up on important details that can help differentiate the noise from the actual image content. This results in the model learning stronger and more useful features, which helps it do a better job of reconstructing clean images. The process of adding noise also acts like a form of regularization, which prevents the model from overfitting and helps it generalize better to new data. In other words, the model becomes better at figuring out the important patterns in the image while ignoring the unnecessary noise.

On the other hand, the Vanilla CNN AE doesn’t have to deal with noisy data, so it doesn’t have that extra challenge. It just learns to compress and reconstruct images, but without the need to clean up noisy inputs. While it works fine for simple image reconstruction, it doesn’t get the benefit of the extra feature learning that happens in the Image Denoising AE.

In short, the Image Denoising AE performs better because it has to deal with the added challenge of denoising images, making it better at capturing important image features and producing cleaner reconstructions, especially when there’s noise or corruption in the input.

**Question 7)** Explain the differences between AE and Variational AE (VAE). Write the answers in paragraph form.

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An Autoencoder (AE) is a type of neural network that is designed to learn a compressed representation (encoding) of input data and then reconstruct it as closely as possible. It consists of two parts: an encoder, which compresses the input, and a decoder, which reconstructs the input from the compressed representation. The objective of an AE is to minimize the reconstruction error, ensuring that the decoded output resembles the original input.

In contrast, a Variational Autoencoder (VAE) is a generative model that not only learns a compressed representation but also imposes a probabilistic structure on the latent space. Instead of encoding the input to a single deterministic point in the latent space like a traditional AE, a VAE encodes the input as a distribution over the latent space. This allows the model to generate new data by sampling from this latent space, making it more suitable for tasks like data generation. The VAE uses two loss terms: one for reconstruction error and another for ensuring the latent space follows a specific distribution (typically a Gaussian). This introduces regularization in the latent space and enables smooth transitions between different points in the latent space, improving the model's generative capabilities.

Thus, while both AEs and VAEs can compress data, VAEs are more powerful for generative tasks due to their probabilistic nature and ability to generate new, coherent samples from the learned latent distribution.