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# Deep Learning - SE4050

# Lab 07

## Question 02

**Relationship Between Linear Autoencoder (AE) and Principal Component Analysis (PCA):**

Linear Autoencoder (AE) and Principal Component Analysis (PCA) are closely related when no activation functions are used in the AE, making it a linear AE. In this case, the linear AE performs a similar function to PCA by projecting data into a lower-dimensional space.

Both methods aim to reduce dimensionality by compressing input data into a smaller latent representation. However, while PCA uses a linear transformation to project data onto the directions of maximum variance (eigenvectors), a linear AE learns this transformation via neural network training.

* **PCA** finds a deterministic, orthogonal transformation based on the covariance matrix of the data.
* **Linear AE** learns an optimized set of weights and biases through backpropagation, potentially giving it more flexibility, but it may still converge to a solution similar to PCA under certain conditions.

## Question 04

**Reasons for Performance Improvements: Dense-Based AE vs. Vanilla CNN AE:**

The **Vanilla CNN AE** is likely to perform better than the **Dense-Based AE** for the following reasons:

1. **Local Feature Learning**: CNNs are capable of capturing local patterns like edges and textures by using convolutional filters. This ability allows CNN-based AEs to learn more relevant features for image reconstruction compared to dense-based AEs, which treat each pixel independently.
2. **Parameter Efficiency**: CNNs share weights across the image via convolutional layers, allowing them to achieve good performance with fewer parameters compared to dense layers.
3. **Spatial Hierarchy**: CNNs can learn hierarchical representations of the data, from low-level features (edges, corners) to high-level patterns (object parts), which enhances image reconstruction performance.

Thus, the **Vanilla CNN AE** is better suited for image-related tasks like the one in the lab, resulting in improved reconstruction accuracy.

## Question 06

**Reasons for Performance Improvements: Vanilla CNN AE vs. Image Denoising AE:**

The **Image Denoising AE** builds upon the **Vanilla CNN AE** by adding noise to the input images, which is a technique known as **denoising**. This has the following benefits:

1. **Regularization**: By adding noise to the input data, the model is encouraged to learn more robust features, reducing its dependency on the training data and mitigating overfitting.
2. **Generalization**: The noise forces the model to generalize better because it has to reconstruct the clean image from a noisy version. This helps the model capture the true underlying patterns in the data, leading to better performance on unseen data.

Overall, the **Image Denoising AE** performs better than the **Vanilla CNN AE** because the denoising process encourages the model to focus on essential, noise-resistant features.

## Question 07

**Differences Between Autoencoder (AE) and Variational Autoencoder (VAE):**

While both AEs and VAEs are used for dimensionality reduction and data reconstruction, they differ in significant ways:

1. **Latent Space**:
   * **AE**: The latent space is not constrained to any specific distribution, which means the latent representations can be arbitrary, and it is harder to generate new data from the AE's latent space.
   * **VAE**: The latent space is constrained to follow a **normal distribution** (e.g., Gaussian). During training, the encoder outputs a mean and variance for each latent variable, and latent vectors are sampled from this distribution. This allows for smooth interpolation in the latent space and makes it easier to generate new samples.
2. **Generative Model**:
   * **AE**: Typically used for tasks like data compression and denoising, but it does not inherently support generating new data.
   * **VAE**: Is a generative model that can be used to generate new data points by sampling from the learned latent distribution. VAEs are widely used for tasks like image generation.
3. **Loss Function**:
   * **AE**: The loss function is typically just the reconstruction error (e.g., Mean Squared Error).
   * **VAE**: The loss function combines the reconstruction loss with a regularization term (the **KL divergence**) that forces the latent space to follow the desired distribution.