DL lab 7 -Autoencoders

1. Upload the Autoencoder (AE) jupyter notebook file (i.e., lab\_7\_AE\_FFNN.ipynb) to google colab root directory.
   * In this code, an image reconstruction is done using dense layers-based AE.
   * Fashion MNIST dataset is used for this task (also for the subsequent tasks as well).
   * Run the above code and understand it.
   * Train the model with 30 epochs.
   * Write the code implementation to calculate the loss (Mean Squared Error) for the test dataset.
   * Write the code implementation to plot the train and validation loss against number of epochs.
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.
3. Upload the Vanilla CNN AE jupyter notebook file (i.e., lab\_7\_AE\_Vanilla\_CNN.ipynb) to google colab root directory.
   * In this code, instead of dense layers, 2D CNN layers are used.
   * Task in the same as before with the same Fashion MNIST dataset.
   * Run the above code and understand it.
   * Train the model with 30 epochs.
   * Write the code implementation to calculate the loss (Mean Squared Error) for the test dataset.
   * Write the code implementation to plot the train and validation loss against number of epochs.
4. Observe the model performance improvements between the above two models and give reasons for the observed improvements.

 **Model Complexity**:

* The simplicity of the convolutional layers with stride 2 downsamples the input effectively, allowing the model to focus on important features while retaining enough spatial information for accurate reconstruction.
* The deeper the network (e.g., more layers or more complex configurations), the better it may capture hierarchical patterns, leading to improved performance.

 **Training Dynamics**:

* Monitoring the losses over epochs allows you to see how well the model converges.
* If you observe steady convergence without overfitting, it's a sign of a balanced model. If the validation loss diverges from the training loss, it indicates overfitting, and adjustments (such as regularization or early stopping) can improve performance.

 **Data Preprocessing**:

* Normalizing the data (scaling pixel values to [0, 1]) ensures the model can learn more effectively. Improper scaling could result in slower or less effective training.

 **Optimization**:

* The choice of adam optimizer with Mean Squared Error (MSE) as the loss function is effective in balancing speed and accuracy. The optimizer dynamically adjusts learning rates, ensuring the model learns efficiently while minimizing loss.

1. Upload the Image De-noising AE jupyter notebook file (i.e., lab\_7\_AE\_CNN\_Image\_Denoising.ipynb) to google colab root directory.
   * In this code, noise is first added to the images before the reconstruction.
   * This is a method to overcome the overfitting that happens in AEs.
   * Run the above code and understand it.
   * Train the model with 30 epochs.
   * Write the code implementation to calculate the loss (Mean Squared Error) for the test dataset.
   * Write the code implementation to plot the train and validation loss against number of epochs.
   * Experiment with “noise\_factor” value and use the best value you find in the final implementation. (Pay attention to how this value affect the images by observing the noise added images in the code.)
2. Observe the model performance improvements between the Image De-noising AE and the Vanilla CNN AE.
   * Explain the reasons for the observed improvements.
3. Explain the differences between AE and Variational AE (VAE).

**Autoencoder (AE):**

* **Goal:** Learn to compress and reconstruct input data.
* **Latent Space:** Fixed, deterministic representation.
* **Reconstruction:** Directly outputs a reconstructed version of the input.
* **Generative Capability:** Limited; primarily used for tasks like compression and denoising.
* **Loss Function:** Only reconstruction loss (e.g., mean squared error).

**Variational Autoencoder (VAE):**

* **Goal:** Learn a probabilistic representation of the input data for generation.
* **Latent Space:** Samples from a learned distribution (mean and variance).
* **Reconstruction:** Samples from the latent space to reconstruct the input, introducing variability.
* **Generative Capability:** Strong; can generate new, realistic data points by sampling.
* **Loss Function:** Combination of reconstruction loss and KL divergence (to regularize the latent space).

**Key Differences:**

* **Latent Representation:** AEs have a fixed point, while VAEs use a distribution.
* **Generative Ability:** VAEs can create new data; AEs cannot.

**Submission.**

Download the final modified notebook files (all 3 jupyter notebooks). Add these notebooks and the word file to a new zip file. Upload this zip file to the courseweb submission link. The file name should be your registration number.