**GitHub repository**:<https://github.com/Isuru-rangana/DL_Lab/tree/main/Lab07/CompletedLab07>

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.

**Both aim to find a lower-dimensional representation of data while preserving as much information as possible.**

* **Both use linear transformations to reduce data dimensionality.**
* **They try to minimize reconstruction error.**
* **The lower-dimensional representation found by a linear autoencoder is very similar to the principal components found by PCA.**
* **The main difference is in how they're implemented:** 
  + **PCA uses direct mathematical calculations.**
  + **Linear autoencoders learn through training, like other neural networks.**

1. 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.
2. Observe the model performance improvements between the above two models and give reasons for the observed improvements.

**The CNN-based autoencoder usually performs better than the dense layer-based autoencoder for image data like Fashion MNIST. The main reasons are:**

1. **Better at understanding images: CNNs are designed to work well with images, capturing important details and patterns.**
2. **More efficient: CNNs use fewer parameters, which helps them learn better without overfitting.**
3. **Spatial awareness: CNNs can understand where things are in an image, which is important for reconstruction.**
4. **Hierarchical learning: CNNs can learn simple features (like edges) and combine them into more complex features, which is great for understanding images.**
5. **Flexibility: CNNs can spot features anywhere in the image, making them more adaptable.**
6. 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.)
7. Observe the model performance improvements between the Image De-noising AE and the Vanilla CNN AE.

Explain the reasons for the observed improvements.

* + **Noise Handling: The Image De-noising AE is trained with artificially noisy input images. This process teaches the model to focus on essential features for reconstruction, resulting in increased robustness and reduced overfitting.**
  + **Generalization: By introducing noise during training, the model effectively gains a regularization effect. This helps it generalize better to unseen data as it learns to filter out irrelevant details and focus on core features.**
  + **Feature Learning: The task of reconstructing clean images from noisy inputs forces the Image De-noising AE to develop a stronger ability to capture important spatial and hierarchical patterns. This enhanced feature learning often leads to better overall performance.**

1. Explain the differences between AE and Variational AE (VAE).

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| Aspect | AE | VAE |
| Basic purpose | Compress and reconstruct data | Generate new data similar to training data |
| Latent space | Fixed representation | Probability distribution |
| Output capability | Can only reconstruct input data | Can generate new, unique data samples |
| Training focus | Minimizing reconstruction error | Balancing reconstruction quality and latent space structure |
| Main applications | Denoising, dimensionality reduction | Generative tasks, working with complex data |
| Randomness | Deterministic | Incorporates randomness |
| Flexibility | Less flexible | More versatile for creative applications |
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**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.