REPORT ON ASSIGNMENT 4

DEEP LEARNING

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Image Classification with Deep Learning

This assignment covers training and evaluating various deep learning models on the Imagenette and CIFAR-10 datasets. The goal is to develop models for image classification tasks and implement techniques like regularization and transfer learning.

1. Basic CNN

Architecture: The basic CNN model was built with several convolutional layers followed by fully connected layers. The architecture aimed for simplicity to establish a baseline model.

Training Details:

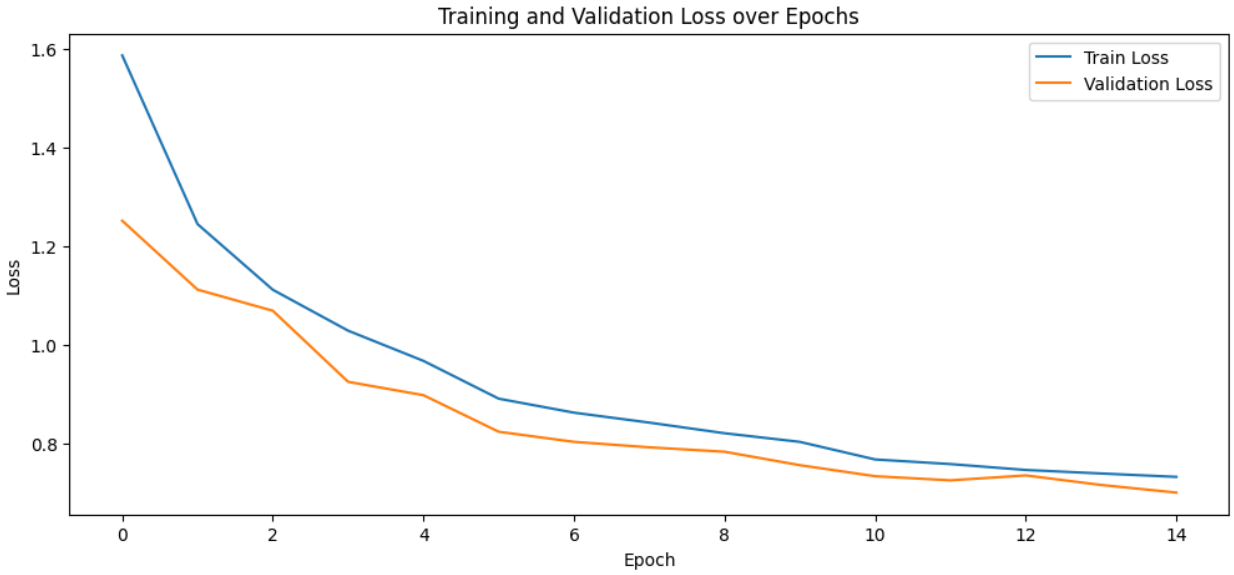
- Early stopping was implemented to prevent overfitting.
- Best Model Path is downloaded and uploaded in the zip file.

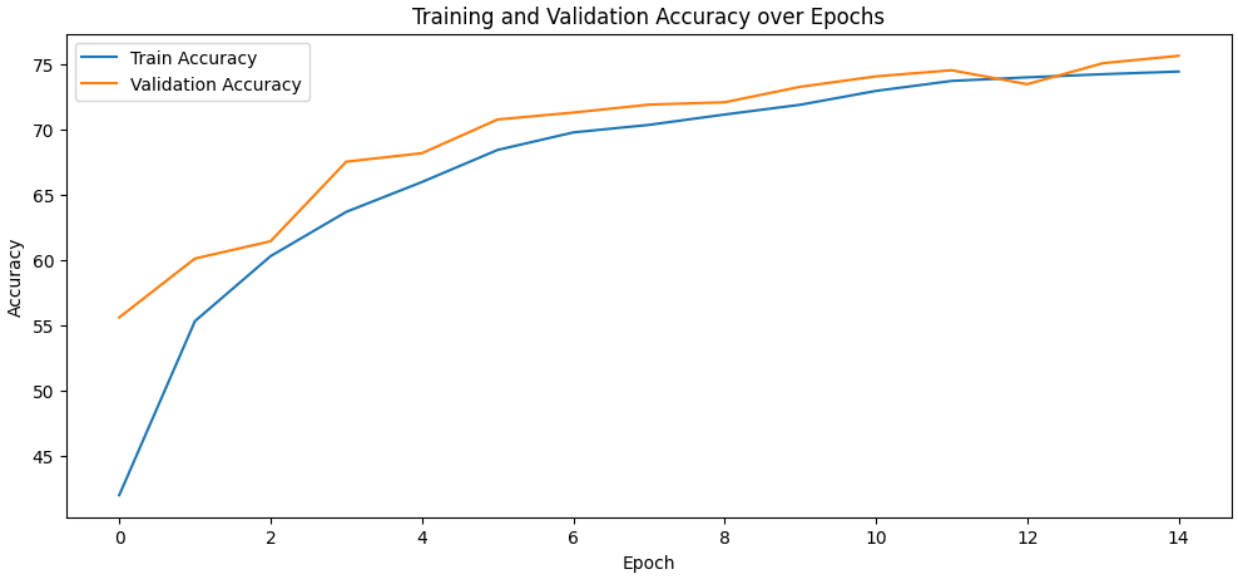
Results:

- **Training Loss**: The model's training loss reduced over epochs, indicating effective learning.

```
Using device: cuda
Files already downloaded and verified
Files already downloaded and verified
Epoch [1/15], Train Loss: 1.5877, Train Acc: 41.95%, Val Loss: 1.2526, Val Acc: 55.60%
Epoch [2/15], Train Loss: 1.2458, Train Acc: 55.31%, Val Loss: 1.1129, Val Acc: 60.12%
Epoch [3/15], Train Loss: 1.1126, Train Acc: 60.30%, Val Loss: 1.0700, Val Acc: 61.45%
Epoch [4/15], Train Loss: 1.0296, Train Acc: 63.70%, Val Loss: 0.9259, Val Acc: 67.56%
Epoch [5/15], Train Loss: 0.9684, Train Acc: 66.00%, Val Loss: 0.8988, Val Acc: 68.21%
Epoch [6/15], Train Loss: 0.8918, Train Acc: 68.46%, Val Loss: 0.8247, Val Acc: 70.80%
Epoch [7/15], Train Loss: 0.8634, Train Acc: 69.81%, Val Loss: 0.8042, Val Acc: 71.33%
Epoch [8/15], Train Loss: 0.8432, Train Acc: 70.39%, Val Loss: 0.7931, Val Acc: 71.94%
Epoch [9/15], Train Loss: 0.8216, Train Acc: 71.18%, Val Loss: 0.7841, Val Acc: 72.12%
Epoch [10/15], Train Loss: 0.8041, Train Acc: 71.93%, Val Loss: 0.7569, Val Acc: 73.31%
Epoch [11/15], Train Loss: 0.7685, Train Acc: 72.99%, Val Loss: 0.7345, Val Acc: 74.11%
Epoch [12/15], Train Loss: 0.7591, Train Acc: 73.76%, Val Loss: 0.7262, Val Acc: 74.58%
Epoch [13/15], Train Loss: 0.7472, Train Acc: 74.03%, Val Loss: 0.7361, Val Acc: 73.51%
Epoch [14/15], Train Loss: 0.7400, Train Acc: 74.28%, Val Loss: 0.7168, Val Acc: 75.12%
Epoch [15/15], Train Loss: 0.7332, Train Acc: 74.48%, Val Loss: 0.7013, Val Acc: 75.69%
<ipython-input-3-b06c2a0c2332>:138: FutureWarning: You are using `torch.load` with `weights_onl
  model.load_state_dict(torch.load("best_model.pth"))
```

- **Validation Loss**: Early stopping was based on validation loss, preventing overfitting.
- **Final Test Accuracy**: The model achieved an accuracy of **74.73%** on the test set.






```
Final Test Accuracy: 74.73%
```

2. ResNet 18

Architecture: ResNet 18, a popular deep learning model for image classification, was chosen for its robustness in handling complex image datasets.

Training Details:

- Early stopping was again implemented to avoid overfitting.

```
Using device: cuda
Downloading https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz to ./data/cifar-10-python.tar.gz
100%|          | 170M/170M [00:03<00:00, 48.1MB/s]
Extracting ./data/cifar-10-python.tar.gz to ./data
Files already downloaded and verified
/usr/local/lib/python3.10/dist-packages/torchvision/models/_utils.py:208: UserWarning: The parameter 'pretrained' is deprecated since 0.13 and may be
  warnings.warn(
/usr/local/lib/python3.10/dist-packages/torchvision/models/_utils.py:223: UserWarning: Arguments other than a weight enum or `None` for 'weights' are
  warnings.warn(msg)
Downloading: "https://download.pytorch.org/models/resnet18-f37072fd.pth" to /root/.cache/torch/hub/checkpoints/resnet18-f37072fd.pth
```

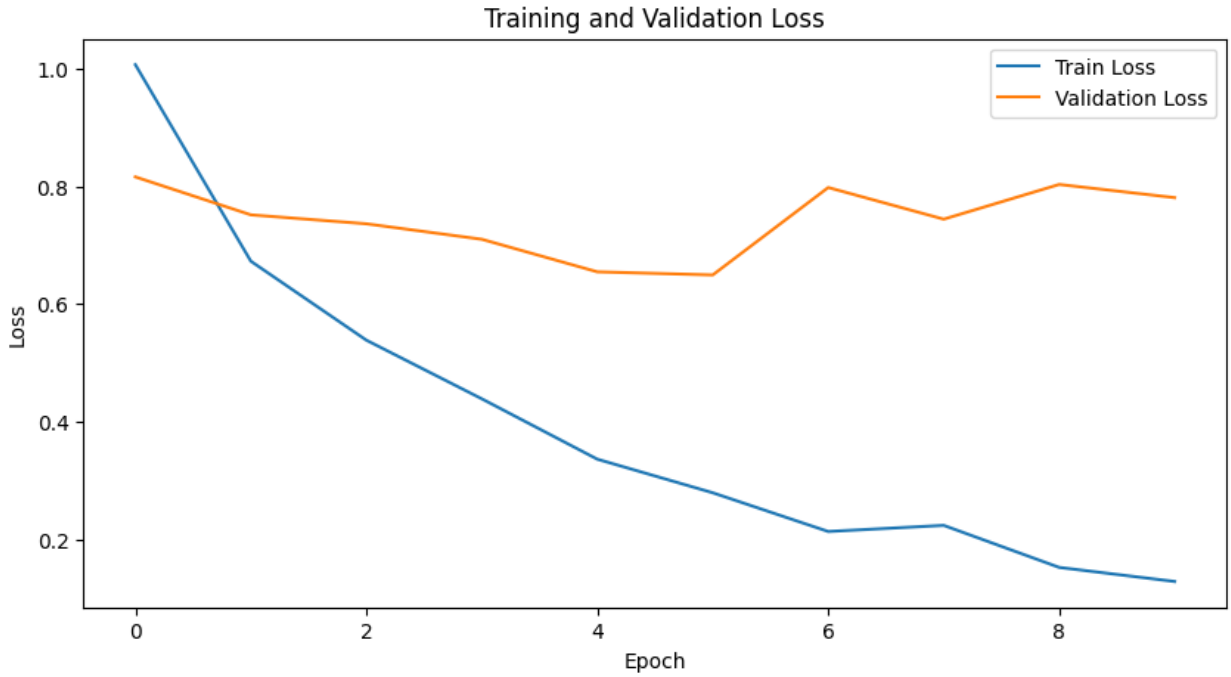
- The model achieved convergence at epoch 8, signaling effective learning.

Results:

- **Training Loss**: The loss decreased with each epoch, showing efficient learning.

```
Epoch [1/10], Train Loss: 1.0068, Validation Loss: 0.8161
Epoch [2/10], Train Loss: 0.6729, Validation Loss: 0.7517
Epoch [3/10], Train Loss: 0.5388, Validation Loss: 0.7365
Epoch [4/10], Train Loss: 0.4391, Validation Loss: 0.7101
Epoch [5/10], Train Loss: 0.3365, Validation Loss: 0.6548
Epoch [6/10], Train Loss: 0.2794, Validation Loss: 0.6495
Epoch [7/10], Train Loss: 0.2137, Validation Loss: 0.7981
Epoch [8/10], Train Loss: 0.2241, Validation Loss: 0.7443
Epoch [9/10], Train Loss: 0.1526, Validation Loss: 0.8033
Epoch [10/10], Train Loss: 0.1287, Validation Loss: 0.7809
```

- **Validation Loss**: Monitored to avoid overfitting, and early stopping was applied.

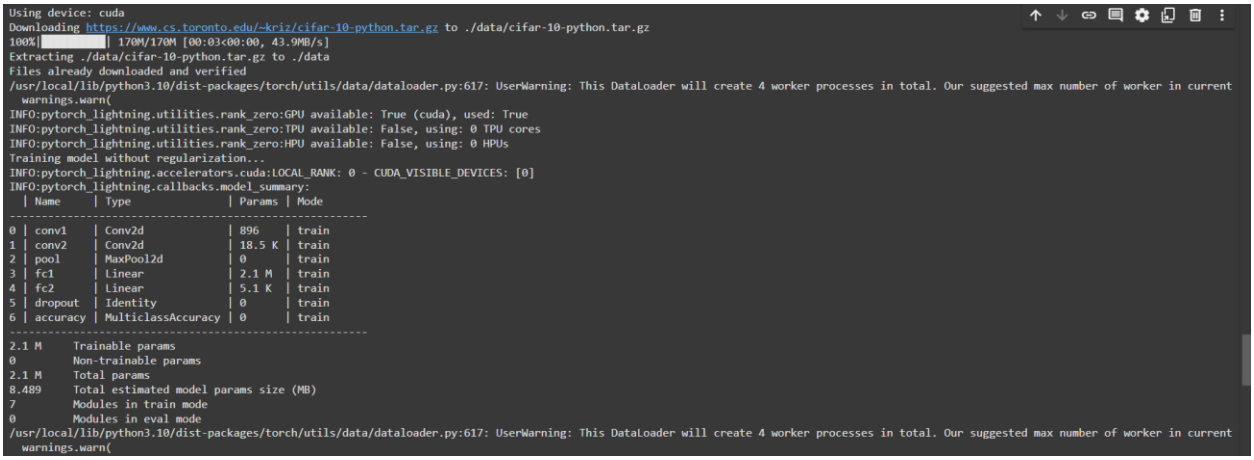


- **Final Test Accuracy**: The ResNet 18 model reached **78.61%** accuracy on the test set.

```
Final Test Accuracy: 78.61%
```

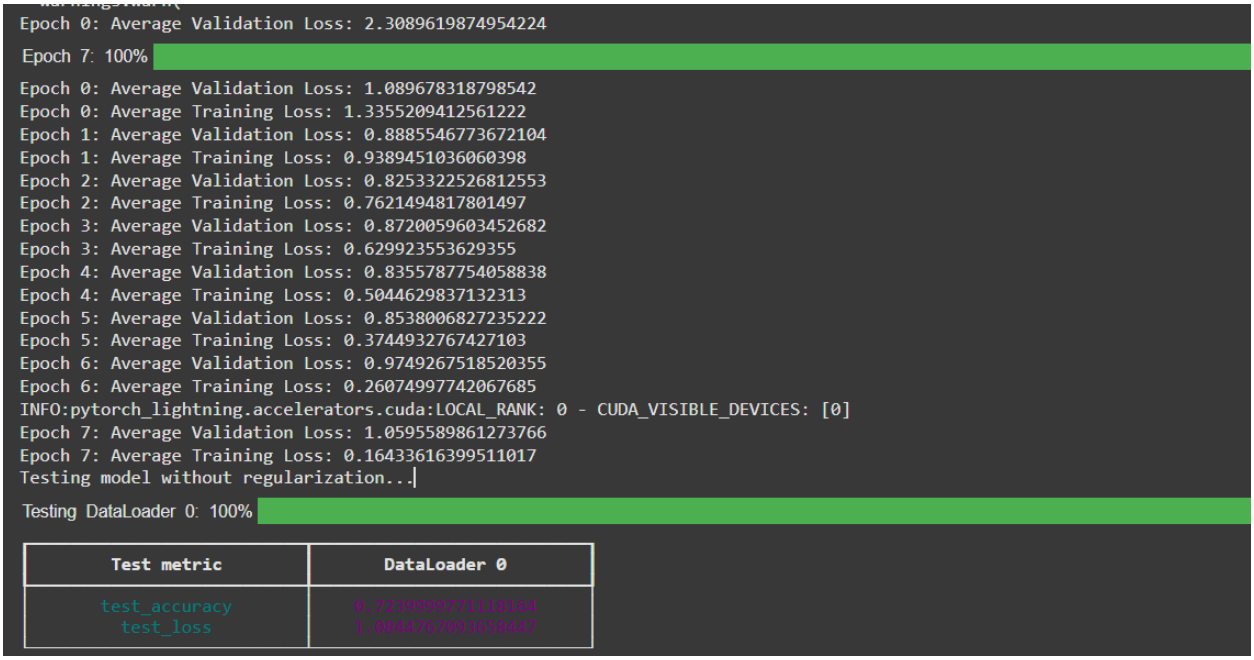
3. Regularization (Data Augmentation)

Approach: To improve generalization, data augmentation was applied to the basic CNN model, introducing random transformations to the input images.

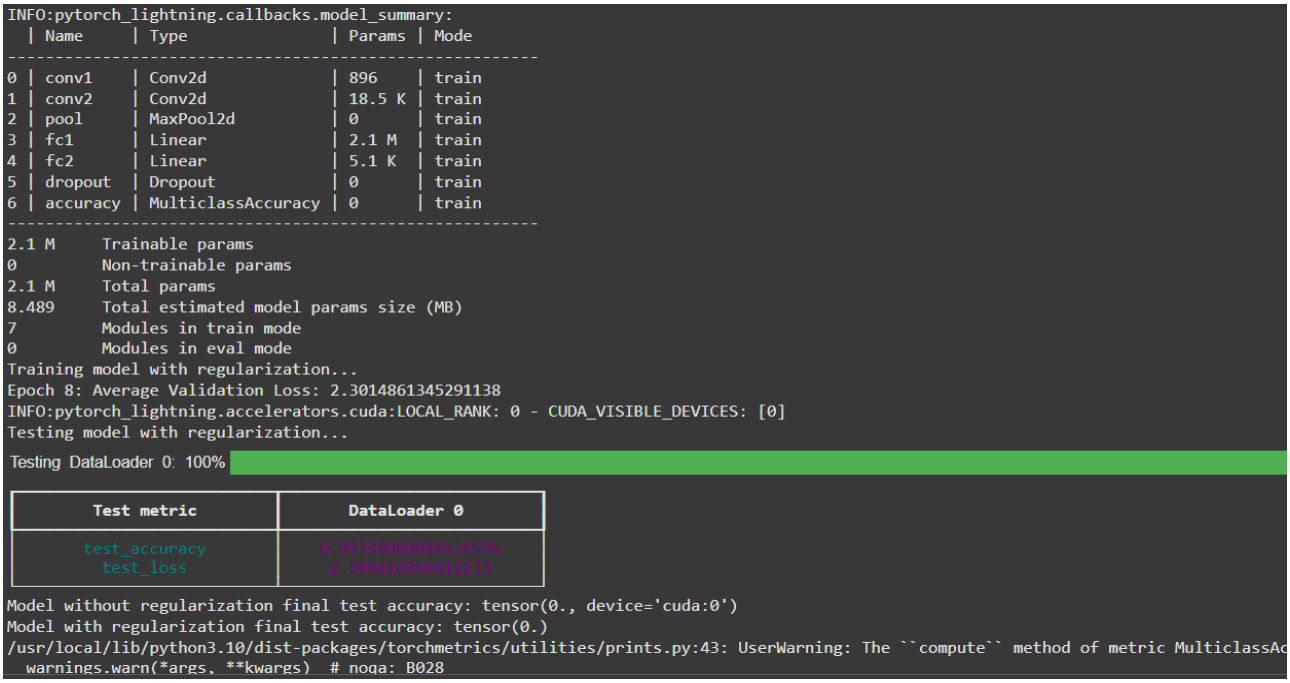


Comparison:

Without Regularization: Accuracy reached 72.39% on the test set and Early stopping at epoch 7.



With Regularization: The test accuracy improved due to data augmentation, yielding better generalization and a slightly higher accuracy.



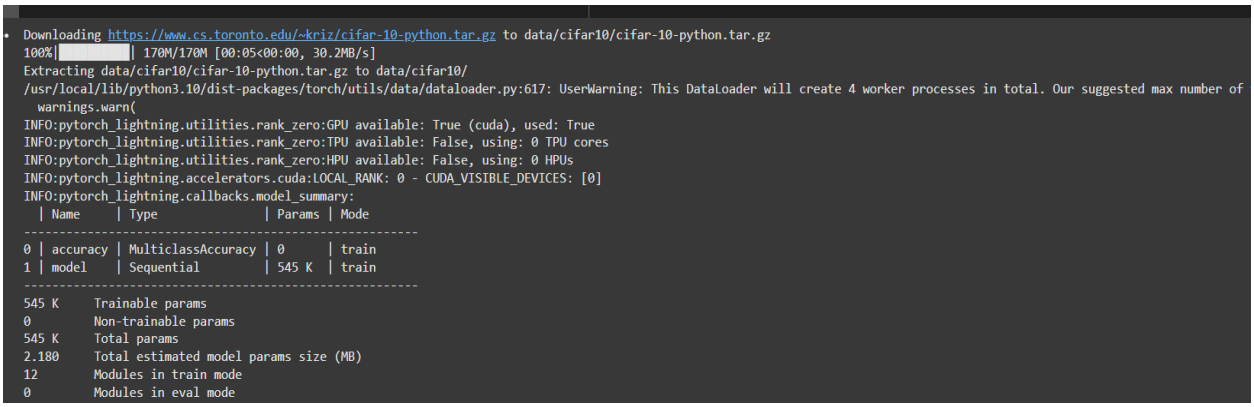
Conclusion:

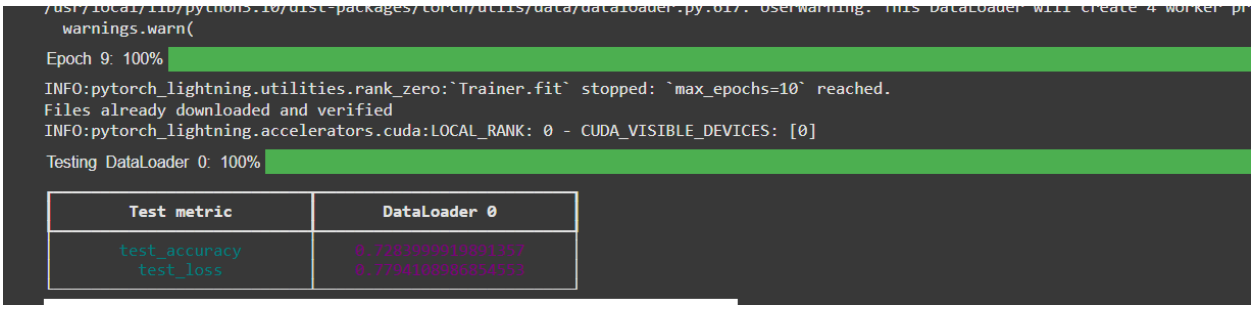
Data augmentation as a regularization method effectively enhanced the model's robustness, slightly increasing test accuracy compared to the non-augmented model.

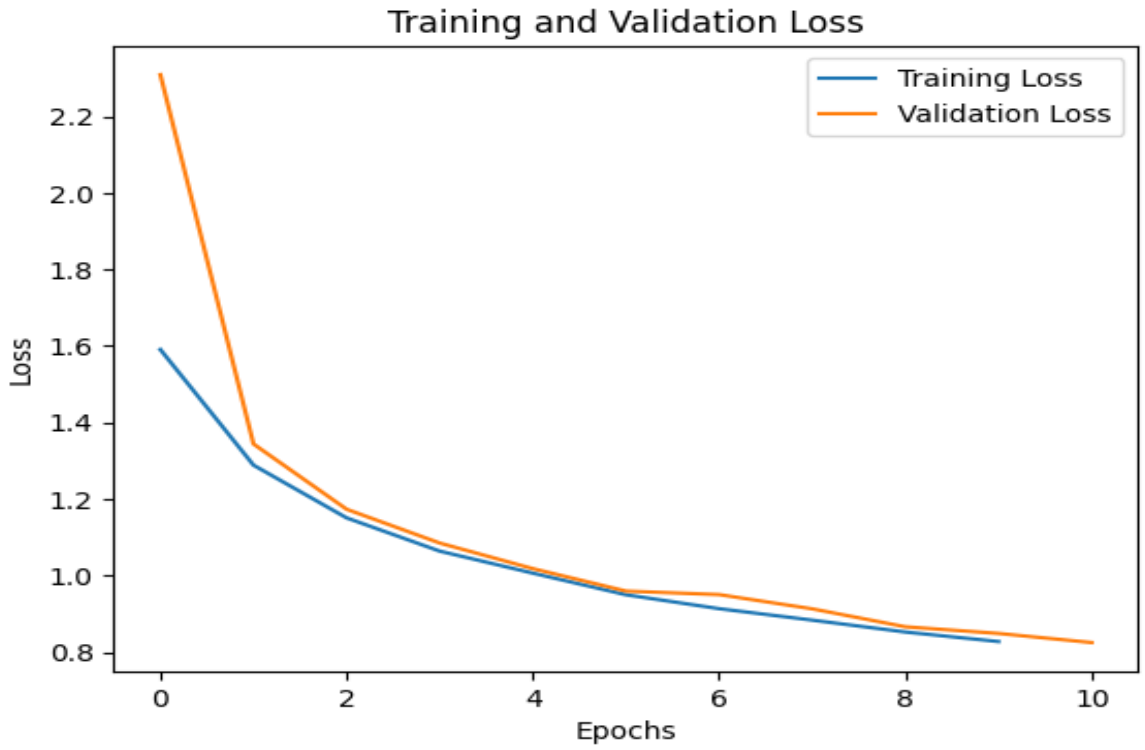
4. Transfer Learning

Process:

Pre-training on Imagenette: The ResNet model was first trained on the Imagenette dataset, achieving reasonable convergence with a test accuracy of **72.16%**.







Fine-tuning on CIFAR-10:

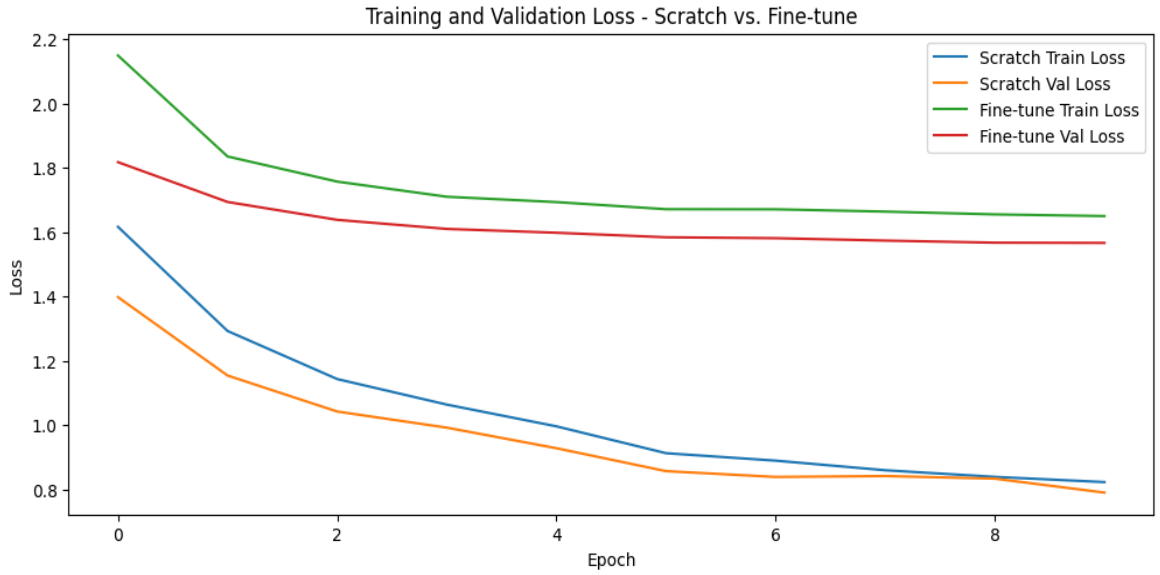
From Scratch: Training the model from scratch on CIFAR-10 achieved a test accuracy of **72.59%**.

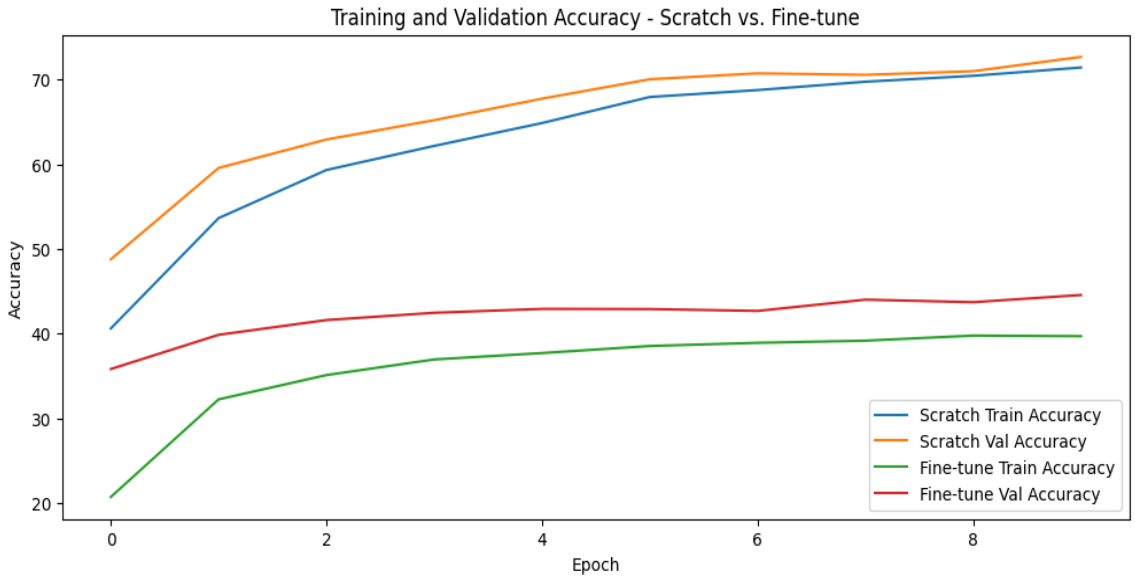
```
Using device: cuda
Downloading and training on Imagenette dataset...
Downloading Imagenette dataset...
Extracting Imagenette dataset...
Download and extraction complete.
Imagenette Training - Epoch [1/10], Loss: 1.7434
Imagenette Training - Epoch [2/10], Loss: 1.3588
Imagenette Training - Epoch [3/10], Loss: 1.1850
Imagenette Training - Epoch [4/10], Loss: 1.0644
Imagenette Training - Epoch [5/10], Loss: 0.9912
Imagenette Training - Epoch [6/10], Loss: 0.9203
Imagenette Training - Epoch [7/10], Loss: 0.8730
Imagenette Training - Epoch [8/10], Loss: 0.8200
Imagenette Training - Epoch [9/10], Loss: 0.7885
Imagenette Training - Epoch [10/10], Loss: 0.7376
Imagenette model saved as 'imagenette_model.pth'
```

Using Pre-trained Weights: Fine-tuning the Imagenette-trained model on CIFAR-10 led to a lower accuracy, with a final test accuracy of **43.61%**.

```
Training from scratch on CIFAR-10 dataset...
Downloading https://www.cs.toronto.edu/~kriz/cifar-10-python.tar.gz to ./data/cifar-10-python.tar.gz
100%|██████████| 170M/170M [00:05<00:00, 30.7MB/s]
Extracting ./data/cifar-10-python.tar.gz to ./data
Files already downloaded and verified
Scratch Epoch [1/10], Train Loss: 1.6163, Train Acc: 40.62%, Val Loss: 1.3980, Val Acc: 48.78%
Scratch Epoch [2/10], Train Loss: 1.2928, Train Acc: 53.64%, Val Loss: 1.1544, Val Acc: 59.56%
Scratch Epoch [3/10], Train Loss: 1.1435, Train Acc: 59.32%, Val Loss: 1.0426, Val Acc: 62.92%
Scratch Epoch [4/10], Train Loss: 1.0642, Train Acc: 62.16%, Val Loss: 0.9925, Val Acc: 65.20%
Scratch Epoch [5/10], Train Loss: 0.9966, Train Acc: 64.86%, Val Loss: 0.9287, Val Acc: 67.74%
Scratch Epoch [6/10], Train Loss: 0.9132, Train Acc: 67.94%, Val Loss: 0.8574, Val Acc: 70.03%
Scratch Epoch [7/10], Train Loss: 0.8901, Train Acc: 68.75%, Val Loss: 0.8394, Val Acc: 70.73%
Scratch Epoch [8/10], Train Loss: 0.8602, Train Acc: 69.74%, Val Loss: 0.8422, Val Acc: 70.55%
Scratch Epoch [9/10], Train Loss: 0.8396, Train Acc: 70.44%, Val Loss: 0.8341, Val Acc: 70.98%
Scratch Epoch [10/10], Train Loss: 0.8234, Train Acc: 71.42%, Val Loss: 0.7908, Val Acc: 72.67%

Fine-tuning pre-trained Imagenette model on CIFAR-10 dataset...
<ipython-input-6-c30dfa702a59>:179: FutureWarning: You are using `torch.load` with `weights_only=False` (the current default value),
  finetune_model.load_state_dict(torch.load("imagenette_model.pth"), strict=False)
Fine-tune Epoch [1/10], Train Loss: 2.1486, Train Acc: 20.73%, Val Loss: 1.8172, Val Acc: 35.83%
Fine-tune Epoch [2/10], Train Loss: 1.8348, Train Acc: 32.25%, Val Loss: 1.6935, Val Acc: 39.87%
Fine-tune Epoch [3/10], Train Loss: 1.7568, Train Acc: 35.12%, Val Loss: 1.6380, Val Acc: 41.61%
Fine-tune Epoch [4/10], Train Loss: 1.7098, Train Acc: 36.96%, Val Loss: 1.6098, Val Acc: 42.47%
Fine-tune Epoch [5/10], Train Loss: 1.6932, Train Acc: 37.72%, Val Loss: 1.5979, Val Acc: 42.93%
Fine-tune Epoch [6/10], Train Loss: 1.6711, Train Acc: 38.55%, Val Loss: 1.5839, Val Acc: 42.91%
Fine-tune Epoch [7/10], Train Loss: 1.6707, Train Acc: 38.92%, Val Loss: 1.5810, Val Acc: 42.69%
Fine-tune Epoch [8/10], Train Loss: 1.6636, Train Acc: 39.18%, Val Loss: 1.5736, Val Acc: 44.02%
Fine-tune Epoch [9/10], Train Loss: 1.6550, Train Acc: 39.78%, Val Loss: 1.5671, Val Acc: 43.72%
Fine-tune Epoch [10/10], Train Loss: 1.6497, Train Acc: 39.71%, Val Loss: 1.5664, Val Acc: 44.57%
```






```
Final Test Accuracy on CIFAR-10:
Scratch Model Test Accuracy: 72.40%
Fine-tuned Model Test Accuracy: 43.52%
```

Conclusion:

While transfer learning typically aids in improving accuracy, the lower performance on CIFAR-10 when using Imagenette-pre-trained weights may indicate insufficient similarity between the two datasets or overfitting during fine-tuning.