# Deep Learning : Multiclass Classification

**Que1: Download a ResNet 50 trained on the ImageNet classification dataset**

**Steps Involved (Common for Part a and b):**

**1. Exploring Dataset**: Dataset used: STL-10
The STL-10 dataset  is an is an image recognition dataset with:
- 10 classes: airplane, bird, car, cat, deer, dog, horse, monkey, ship, truck.
- Train Dataset Size:  5000                              Shape:  (5000, 3, 96, 96)
- Test Dataset Size:  8000                               Shape:  (8000, 3, 96, 96)
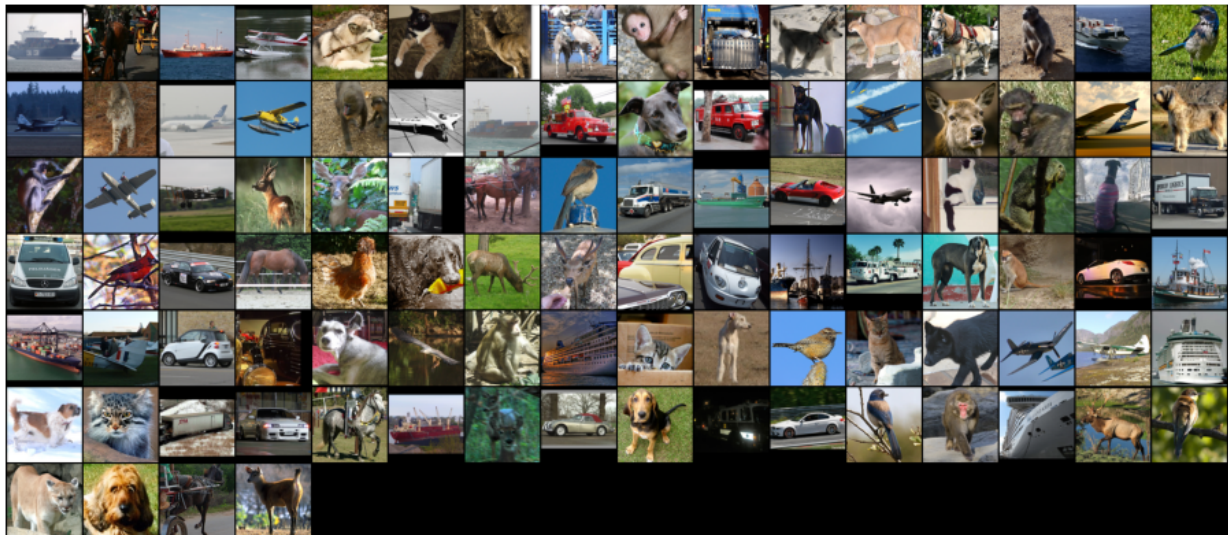- Count of Images belonging to each class: 500 each

```
{'airplane': 500,'bird': 500,'car': 500,'cat': 500,'deer': 500,
  'dog': 500,'horse': 500,'monkey': 500,'ship': 500,'truck': 500}
```

- Images are 96x96 pixels, color.
- 500 training images (10 pre-defined folds), 800 test images per class.

**2. Data Preprocessing:** Transformed the data with following operations
- `Resize((255,255)),`
- `CenterCrop(224),`
- `Convert to Tensor`
- `Normalize([0.5,0.5,0.5],[0.5,0.5,0.5])`

2. Created a Train and Test Data Loaders each of batch size 100.
3. Visualizing a batch of data



4. Moved data and labels to GPU if available.

**a) Use the features extracted from the last fully-connected layer and train a multiclass SVM classifier on STL-10 dataset. Report the following**
**i. Accuracy, Confusion Matrix on test data.**
**ii. ROC curve**

## 1. Link of Google Colab Code File:

https://colab.research.google.com/drive/1ROVDFwSNdWJj7jjHxUWwM0flXmsedHE-?usp=sharing

2. Used a pre trained Resnet50 model for feature extraction by removing the last fully connected layer of the model

FC layer removed: `Linear-174       [-1, 1000]        2,049,000`

Last layer of Resnet50 model after removing FC layer:
`AdaptiveAvgPool2d-173               [-1, 2048, 1, 1]             0`
`Total params: 23,508,032`

3. Used the features extracted from the pretrained Resnet50 model as X_train to train a new model for multiclass classification using SVM classifier.

Shape of X_train: (5000, 2048) indicating a total of 5000 data points with each image being represented as 2048 feature columns.
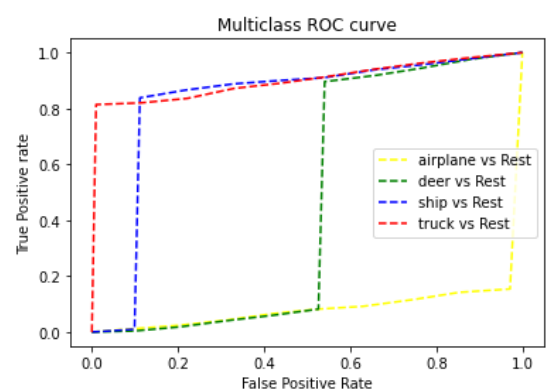Length of Y_train: 5000, containing the class label for each of the images
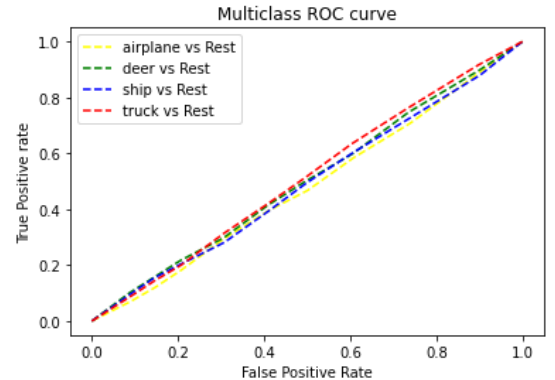
SVM Classifier used to train the model:

| Kernel | Gamma | Regularizing factor (C) |
|---|---|---|
| 'rbf' | 0.001 | 200 |

## 4. Observation:

<u>4.1. Train Data</u>

| Accuracy | Confusion Matrix | ROC Curve |
|---|---|---|
| 82.66% | [[423   6  13  12   5   8  12   9   6   6]<br>[  8 433   9   9   5   9   8   7   9   3]<br>[ 18  18 404   9   8   7  13  10   5   8]<br>[ 17   9   8 427   8   6   8   6   9   2]<br>[ 12  16  13  11 407  11  10  11   7   2]<br>[  9  12  13  18  10 408  12   8   5   5]<br>[ 18  10  10   9   8  11 403  15  10   6]<br>[ 27  11   6  12   5   8  15 407   2   7]<br>[ 11  11   9  14   5   6  11  14 414   5]<br>[  9  10  11  14  11   9  18   8   3 407]] |  |

| Accuracy | Confusion Matrix | ROC Curve |
|---|---|---|
| 10.32% | [[ 88 146  98  94  58  81  88  51  40  56]<br> [ 84 139 103  78  70  88  80  47  48  63]<br> [ 78 117 106  91  68  77  82  60  38  83]<br> [ 84 123 100  82  80  80  76  51  56  68]<br> [ 82 121 117  79  70  93  65  49  44  80]<br> [ 82 143 110  86  59  84  80  49  41  66]<br> [ 70 142 101  87  70  84  79  56  42  69]<br> [ 72 130 103  87  81  68  87  50  47  75]<br> [ 96 124  98  87  80  90  62  41  47  75]<br> [ 67 124 102  96  76  86  89  46  45  69]] |  Multiclass ROC curve |

**b) Fine-tune the ResNet 50 model for the STL-10 dataset, and evaluate the classification performance on the test set before and after fine-tuning with respect to the following metrics**
 **i. Class wise Accuracy**
**ii. Report Confusion Matrix.**

**1. Link of Google Colab Code File:**
https://colab.research.google.com/drive/1jgnRkJkUu2K-8OeSVQN6zkdS6c4kW7r9?usp=sharing

**2. Observation:**

**2.1. Pretrained ResNet50 model (Before Fine Tuning)**
    i. Accuracy on test data: 82.0%
    ii. Class Wise accuracy:

| Class | Accuracy |
|---|---|
| Airplane | 84.25% |
| Bird | 86.75% |
| Car | 82.38% |
| Cat | 77.75% |
| Deer | 78.5% |
| Dog | 71.88% |
| Horse | 84.0% |
| Monkey | 81.5% |
| Ship | 90.75% |
| Truck | 84.5% |

## 2.2. Fine Tuned Resnet50 model:

Added following layers to the pretrained Resnet50 model and changed the output class from 1000 to 10 as the total classes present in the STL10 dataset is 10.

```
AdaptiveAvgPool2d-173          [-1, 2048, 1, 1]              0
       BatchNorm1d-174              [-1, 2048]          4,096
          Dropout-175              [-1, 2048]              0
           Linear-176              [-1, 2048]      4,196,352
             ReLU-177              [-1, 2048]              0
       BatchNorm1d-178              [-1, 2048]          4,096
          Dropout-179              [-1, 2048]              0
           Linear-180                [-1, 10]         20,490
================================================================
Total params: 27,733,066
Trainable params: 27,733,066
Non-trainable params: 0
----------------------------------------------------------------
```

### 2.2.1. Trained the Fine tuned ResNet50 model:

| No. of Epochs | Loss Function | Optimizer | Training Accuracy |
|---|---|---|---|
| 10 | CrossEntropyLoss | Adam | 98.36% |

```
Epoch: 0 Loss :0.2538050718545914  Accuracy :92.34%
Epoch: 1 Loss :0.12460703556537628  Accuracy :95.74000000000001%
Epoch: 2 Loss :0.09275018665790558  Accuracy :97.06%
Epoch: 3 Loss :0.06733751568389125  Accuracy :97.56%
Epoch: 4 Loss :0.048290332701802254  Accuracy :98.34%
Epoch: 5 Loss :0.0700740644901991  Accuracy :97.46000000000001%
Epoch: 6 Loss :0.060362133127450944  Accuracy :98.14%
Epoch: 7 Loss :0.05540539839863777  Accuracy :98.02%
Epoch: 8 Loss :0.048702784439921376  Accuracy :98.42%
Epoch: 9 Loss :0.04847560664564371  Accuracy :98.36%
Finished Training
```

### 2.2.2. Evaluation on Test Data
i. Accuracy on Test data: 95.0%
ii. Class wise Accuracy:

| Class | Accuracy |
|---|---|
| Airplane | 97.5% |
| Bird | 97.38% |
| Car | 97.38% |
| Cat | 95.88% |

| | |
|---|---|
| Deer | 92.62% |
| Dog | 91.75% |
| Horse | 95.25% |
| Monkey | 97.75% |
| Ship | 95.62% |
| Truck | 97.75% |