# Assignment 5

This is an basecode for assignment 5 of Artificial Intelligence class (CSCE-4613), Spring 2025

```
import torch
import torchvision
import torch.nn as nn
from torchvision import transforms

from PIL import Image
import pickle
import matplotlib.pyplot as plt
```

# Question 1

## Define Input Transformation

```
MEAN = [0.485, 0.456, 0.406]
STD = [0.229, 0.224, 0.225]
IMAGE_SIZE = 224
image_transforms = transforms.Compose([
                           transforms.Resize(IMAGE_SIZE),
                           transforms.CenterCrop(IMAGE_SIZE),
                           transforms.ToTensor(),
                           transforms.Normalize(mean = MEAN, std = STD)])

index2name = pickle.load(open("imagenet_class_names.pkl", "rb"))
```

## Define Model

```
model = torchvision.models.resnet50(pretrained=True)
softmax_layer = nn.Softmax(dim=1)
model.eval()
```

```
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (4): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
    (5): Bottleneck(
      (conv1): Conv2d(1024, 256, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv2): Conv2d(256, 256, kernel_size=(3, 3), stride=(1, 1), padding=(1, 1),
bias=False)
      (bn2): BatchNorm2d(256, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv3): Conv2d(256, 1024, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn3): BatchNorm2d(1024, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (relu): ReLU(inplace=True)
    )
  )
  (layer4): Sequential(
    (0): Bottleneck(
      (conv1): Conv2d(1024, 512, kernel_size=(1, 1), stride=(1, 1), bias=False)
      (bn1): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
      (conv2): Conv2d(512, 512, kernel_size=(3, 3), stride=(2, 2), padding=(1, 1),
bias=False)
      (bn2): BatchNorm2d(512, eps=1e-05, momentum=0.1, affine=True,
track_running_stats=True)
```

## Classify and Visualize Image

```
image_path = "dog.jpg"
original_image = Image.open(image_path).convert("RGB")
image = image_transforms(original_image)
image = image.unsqueeze(0)
output = softmax_layer(model(image))

prediction = torch.argmax(output, dim=1).item()
prob = output[0, prediction].item() * 100
predicted_name = index2name[prediction]

plt.imshow(original_image)
plt.title("Class: %s. Probabilty: %.2f" % (predicted_name, prob) + "%")
plt.axis("off")
plt.show()
```


## Get Top-K Predictions

```
K = 5
# Write your code to get the top-K predictions (top K classes that have highest prol
top_k_values, top_k_indices = torch.topk(output, K, dim=1)
top_k_probs = top_k_values[0].tolist()
top_k_classes = top_k_indices[0].tolist()

# Print top-K predictions
print("Top {} predictions:".format(K))
for i in range(K):
    class_name = index2name[top_k_classes[i]]
    probability = top_k_probs[i] * 100
    print("{}. {} - {:.2f}%".format(i+1, class_name, probability))
```

```
Top 5 predictions:
1. golden retriever - 93.91%
2. Labrador retriever - 3.65%
3. Brittany spaniel - 0.69%
```

```
4. clumber, clumber spaniel - 0.30%
5. tennis ball - 0.29%
```

# Question 2

## Define Training Data Loader

```
train_batch_size = 32
train_transforms = transforms.Compose([
    transforms.RandomHorizontalFlip(),
    transforms.RandomCrop(32, padding=4),
    transforms.ToTensor(),
    transforms.Normalize((0.4914, 0.4822, 0.4465), (0.2470, 0.2435, 0.2616))
])

# Define training dataset and data loader
train_dataset = torchvision.datasets.CIFAR10(root='data/CIFAR-10', train=True,
                                            download=True, transform=train_transforms)
train_loader = torch.utils.data.DataLoader(train_dataset, batch_size=train_batch_size,
                                          shuffle=True, num_workers=2)
```

```
100%|██████████| 170M/170M [00:03<00:00, 48.3MB/s]
```

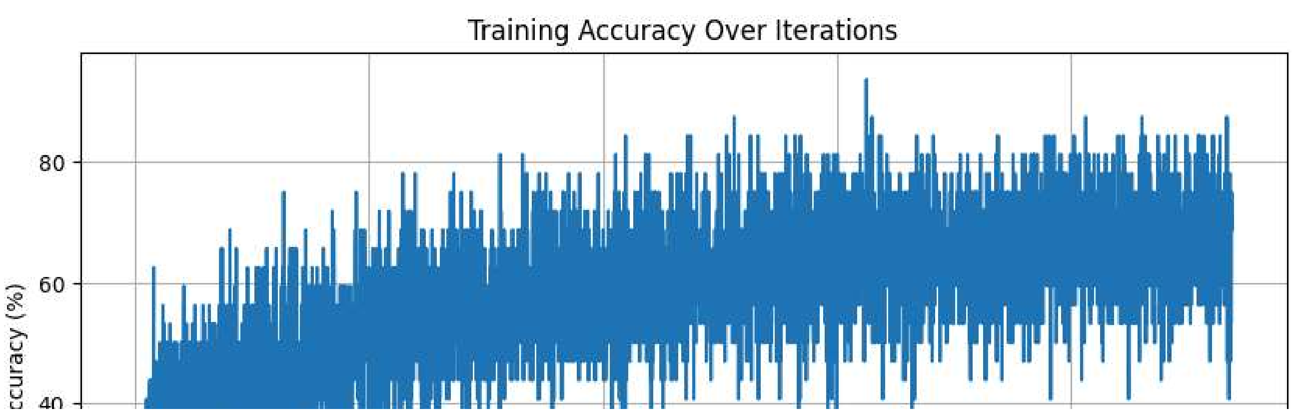
# Define Model and Training Framework

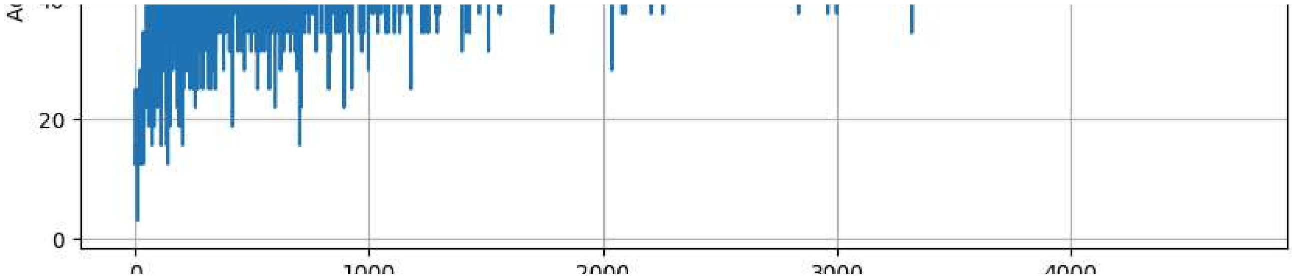
```
cuda = torch.cuda.is_available()
# model = None # Define a classification model for 10 classes
# Define a simple CNN for CIFAR-10
class CIFAR10CNN(nn.Module):
    def __init__(self):
        super(CIFAR10CNN, self).__init__()
        # Convolutional layers
        self.conv1 = nn.Conv2d(3, 32, kernel_size=3, padding=1)
        self.conv2 = nn.Conv2d(32, 64, kernel_size=3, padding=1)
        self.conv3 = nn.Conv2d(64, 128, kernel_size=3, padding=1)

        # Pooling layer
        self.pool = nn.MaxPool2d(2, 2)

        # Fully connected layers
        self.fc1 = nn.Linear(128 * 4 * 4, 512)
        self.fc2 = nn.Linear(512, 10)

        # Dropout
        self.dropout = nn.Dropout(0.2)

        # Batch normalization
        self.bn1 = nn.BatchNorm2d(32)
        self.bn2 = nn.BatchNorm2d(64)
        self.bn3 = nn.BatchNorm2d(128)

    def forward(self, x):
        # Apply convolution, batch norm, ReLU, and pooling
        x = self.pool(torch.relu(self.bn1(self.conv1(x))))
        x = self.pool(torch.relu(self.bn2(self.conv2(x))))
        x = self.pool(torch.relu(self.bn3(self.conv3(x))))

        # Flatten
        x = x.view(-1, 128 * 4 * 4)

        # Fully connected with dropout
        x = self.dropout(torch.relu(self.fc1(x)))
        x = self.fc2(x)

        return x

# Initialize the model
model = CIFAR10CNN()

if cuda:
  model.cuda()

model.train()
learning_rate = 0.001
num_epochs = 3
optim = torch.optim.Adam(model.parameters(), lr = learning_rate)
loss_fn = nn.CrossEntropyLoss()
```

```
    loss_logger = []
    accuracy_logger = []

    for epoch in range(1, num_epochs + 1):
      for it, (images, labels) in enumerate(train_loader):
          if cuda:
            images = images.cuda()
            labels = labels.cuda()

          # Write your code to computer outputs, loss, accuracy, and optimize model
          # outptus = ???
          # loss = ???
          # accuracy = ???
          # optimize the model
          # loss = None
          # accuracy = None
                # Forward pass
          outputs = model(images)
          loss = loss_fn(outputs, labels)

          # Backward and optimize
          optim.zero_grad()
          loss.backward()
          optim.step()

          # Calculate accuracy
          _, predicted = torch.max(outputs.data, 1)
          total = labels.size(0)
          correct = (predicted == labels).sum().item()
          accuracy = correct / total * 100

          loss_logger.append(loss.item())
          accuracy_logger.append(accuracy)

          if it % 200 == 0:
            print("Epoch [%d/%d]. Iter [%d/%d]. Loss: %0.4f. Accuracy: %.2f" % (epoch, num_epochs,

    torch.save(model.state_dict(), "CIFAR10-Model.pth")

    # Write your code to visualize the training losses over interations
    plt.figure(figsize=(10, 5))
    plt.plot(loss_logger)
    plt.title('Training Loss Over Iterations')
    plt.xlabel('Iteration')
    plt.ylabel('Loss')
    plt.grid(True)
    plt.show()

    # Write your code to visualize the training accuracies over interations
    plt.figure(figsize=(10, 5))
    plt.plot(accuracy_logger)
    plt.title('Training Accuracy Over Iterations')
```

```
plt.xlabel('Iteration')
plt.ylabel('Accuracy (%)')
plt.grid(True)
plt.show()
```

```
Epoch [1/3]. Iter [1/1563]. Loss: 2.2916. Accuracy: 12.50
Epoch [1/3]. Iter [201/1563]. Loss: 1.4965. Accuracy: 40.62
Epoch [1/3]. Iter [401/1563]. Loss: 1.5610. Accuracy: 46.88
Epoch [1/3]. Iter [601/1563]. Loss: 1.4966. Accuracy: 40.62
Epoch [1/3]. Iter [801/1563]. Loss: 1.4353. Accuracy: 43.75
Epoch [1/3]. Iter [1001/1563]. Loss: 1.1127. Accuracy: 62.50
Epoch [1/3]. Iter [1201/1563]. Loss: 1.2591. Accuracy: 56.25
Epoch [1/3]. Iter [1401/1563]. Loss: 1.1439. Accuracy: 56.25
Epoch [2/3]. Iter [1/1563]. Loss: 1.4925. Accuracy: 46.88
Epoch [2/3]. Iter [201/1563]. Loss: 0.9655. Accuracy: 59.38
Epoch [2/3]. Iter [401/1563]. Loss: 0.8149. Accuracy: 71.88
Epoch [2/3]. Iter [601/1563]. Loss: 1.0035. Accuracy: 62.50
Epoch [2/3]. Iter [801/1563]. Loss: 1.0080. Accuracy: 65.62
Epoch [2/3]. Iter [1001/1563]. Loss: 1.1147. Accuracy: 62.50
Epoch [2/3]. Iter [1201/1563]. Loss: 1.0802. Accuracy: 65.62
Epoch [2/3]. Iter [1401/1563]. Loss: 0.7983. Accuracy: 68.75
Epoch [3/3]. Iter [1/1563]. Loss: 0.9694. Accuracy: 65.62
Epoch [3/3]. Iter [201/1563]. Loss: 1.0216. Accuracy: 62.50
Epoch [3/3]. Iter [401/1563]. Loss: 0.7440. Accuracy: 71.88
Epoch [3/3]. Iter [601/1563]. Loss: 0.8917. Accuracy: 62.50
Epoch [3/3]. Iter [801/1563]. Loss: 0.8521. Accuracy: 71.88
Epoch [3/3]. Iter [1001/1563]. Loss: 1.3275. Accuracy: 59.38
Epoch [3/3]. Iter [1201/1563]. Loss: 0.7498. Accuracy: 81.25
Epoch [3/3]. Iter [1401/1563]. Loss: 0.7952. Accuracy: 71.88
```




## Load Model and Evaluate Model On Testing Dataset

```
cuda = torch.cuda.is_available()
# model = # Define a classification model for 10 classes
model = CIFAR10CNN()
if cuda:
  model.cuda()

# Load your trained model in the previous step
model.load_state_dict(torch.load("CIFAR10-Model.pth"))
model.eval()

# test_dataset = None # Define Testing Set of CIFAR-10
# test_loader = None # Define Testing Loader of CIFAR-10
# Define test dataset and loader
test_transforms = transforms.Compose([
    transforms.ToTensor(),
    transforms.Normalize((0.4914, 0.4822, 0.4465), (0.2470, 0.2435, 0.2616))
])

test_dataset = torchvision.datasets.CIFAR10(root='data/CIFAR-10', train=False,
                                            download=True, transform=test_transforms
test_loader = torch.utils.data.DataLoader(test_dataset, batch_size=100,
                                          shuffle=False, num_workers=2)
all_predictions = []
all_labels = []

final_accuracy = 0.0
final_top_5_acuuracy = 0.0


for it, (images, labels) in enumerate(test_loader):
  if cuda:
    images = images.cuda()
    labels = labels.cuda()

    # Write your code to computer outputs, accuracy, and top 5 accuracy
    # outptus = ???
    # accuracy = ???
    # top_5_acuuracy = ???
    # accuracy = None
    # top_5_acuuracy = None
 # Forward pass
```

```
        outputs = model(images)

        # Calculate accuracy
        _, predicted = torch.max(outputs.data, 1)
        total = labels.size(0)
        correct = (predicted == labels).sum().item()
        accuracy = correct / total * 100

        # Calculate top-5 accuracy
        _, top5_indices = torch.topk(outputs, 5, dim=1)
        batch_correct = 0
        for i in range(len(labels)):
            if labels[i] in top5_indices[i]:
                batch_correct += 1
        top_5_acuuracy = batch_correct / total * 100
        all_predictions.extend(predicted.cpu().numpy())
        all_labels.extend(labels.cpu().numpy())
        final_accuracy += accuracy
        final_top_5_acuuracy += top_5_acuuracy

        if it % 500 == 0:
          print("Iter [%d/%d]. Accuracy: %.2f" % (it + 1, len(test_loader), accuracy))

      print("Final Accuracy: %0.2f" % (final_accuracy / len(test_loader)))
      print("Top 5 Accuracy: %0.3f" % (top_5_acuuracy / len(test_loader)))

      from sklearn.metrics import confusion_matrix
      import numpy as np
      import seaborn as sns

      # CIFAR-10 class names
      class_names = ['airplane', 'automobile', 'bird', 'cat', 'deer', 'dog', 'frog', 'hor
      cm = confusion_matrix(all_labels, all_predictions)
```