Lab2: Adversarial Attacks on Deep Neural Networks

Load Dataset

```
import tensorflow as tf
from tensorflow.keras.datasets import mnist, cifar10, cifar100
from tensorflow.keras import Sequential
from tensorflow.keras.callbacks import LambdaCallback
from tensorflow.keras.layers import Conv2D, MaxPooling2D, Dropout, Dense, Flat
import numpy as np
import pandas as pd
import random
import matplotlib.pyplot as plt
```

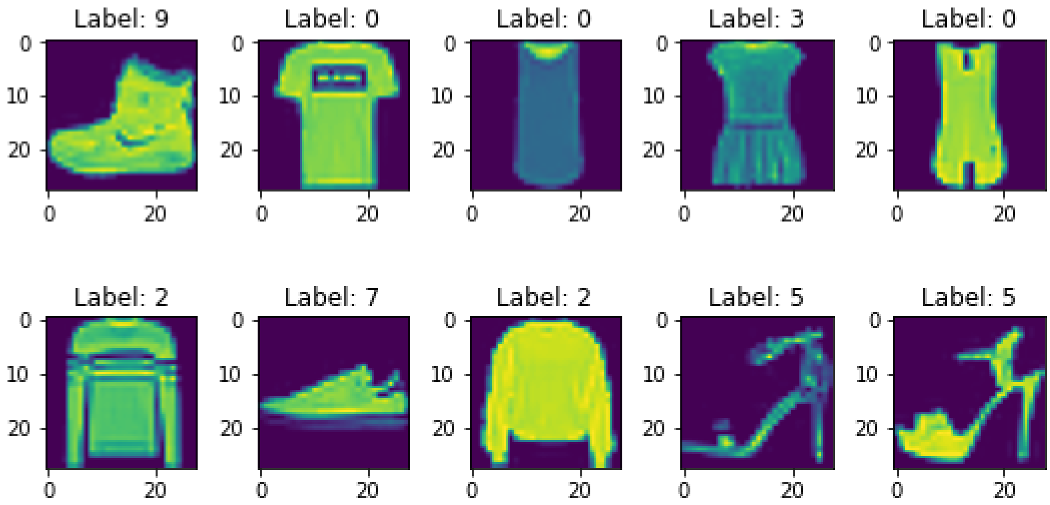
```
#loading the MNIST
fashion_mnist = tf.keras.datasets.fashion_mnist
(xTrain, yTrain), (xTest, yTest) = fashion_mnist.load_data()
```

```
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datas
32768/29515 [=================================] - 0s 0us/step
40960/29515 [=========================================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datas
26427392/26421880 [==============================] - 0s 0us/step
26435584/26421880 [==============================] - 0s 0us/step
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datas
16384/5148 [==================================================================
Downloading data from https://storage.googleapis.com/tensorflow/tf-keras-datas
4423680/4422102 [==============================] - 0s 0us/step
4431872/4422102 [==============================] - 0s 0us/step
```

```
# Plot picture
plt.figure()
plt.imshow(xTrain[0])
plt.colorbar()
plt.grid(False)
plt.show()
```


```
num = 10
images = xTrain[:num]
labels = yTrain[:num]

num_row = 2
num_col = 5 # plot images
fig, axes = plt.subplots(num_row, num_col, figsize=(1.5*num_col,2*num_row))
for i in range(num):
    ax = axes[i//num_col, i%num_col]
    ax.imshow(images[i])
    ax.set_title('Label: {}'.format(labels[i]))
plt.tight_layout()
plt.show()
```




```
xTrain[0].shape
```

```
(28, 28)
```

```
# Preprocessing
img_rows, img_cols = xTrain[0].shape
numOfClasses = 10

xTrain = xTrain / 255.0
xTest = xTest / 255.0
```

Baseline DNN

Q1: Implement baseline DNN

```
baseModel = tf.keras.models.Sequential([
    tf.keras.layers.Flatten(input_shape=(28, 28)),
    tf.keras.layers.Dense(128, activation='relu'),
    tf.keras.layers.Dropout(0.2),
```

```
    tf.keras.layers.Dense(10)
])
baseModel.compile(optimizer='adam',
              loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=Tru
              metrics=['accuracy'])
baseModel.fit(xTrain, yTrain, epochs=10)
```

```
Epoch 1/10
1875/1875 [==============================] - 4s 2ms/step - loss: 0.5351 - accu
Epoch 2/10
1875/1875 [==============================] - 4s 2ms/step - loss: 0.4008 - accu
Epoch 3/10
1875/1875 [==============================] - 4s 2ms/step - loss: 0.3672 - accu
Epoch 4/10
1875/1875 [==============================] - 4s 2ms/step - loss: 0.3444 - accu
Epoch 5/10
1875/1875 [==============================] - 4s 2ms/step - loss: 0.3307 - accu
Epoch 6/10
1875/1875 [==============================] - 4s 2ms/step - loss: 0.3190 - accu
Epoch 7/10
1875/1875 [==============================] - 4s 2ms/step - loss: 0.3075 - accu
Epoch 8/10
1875/1875 [==============================] - 4s 2ms/step - loss: 0.2982 - accu
Epoch 9/10
1875/1875 [==============================] - 4s 2ms/step - loss: 0.2919 - accu
Epoch 10/10
1875/1875 [==============================] - 4s 2ms/step - loss: 0.2821 - accu
<keras.callbacks.History at 0x7f2f91d7f910>
```

```
print("Base loss and accuracy on regular images:", baseModel.evaluate(x=xTest, y
```

```
Base loss and accuracy on regular images: [0.3400658667087555, 0.880100011825
```

FGSM based untargeted attacks

Q2: Implement FGS untargetd attack

```
def get_prtbtns(X, label, loss_func, model):
    perturbations = np.zeros((X.shape[0], X.shape[1], X.shape[2]))
    for i in range(X.shape[0]):
        x,y = X[i:i+1],label[i]
        with tf.GradientTape() as gt:
            gt.watch(x)
            p = model(x)
            loss = loss_func(y, p)
        grad = gt.gradient(loss, x)
        perturbations[i] = tf.sign(grad)
    return perturbations

xTest_tensor = tf.convert_to_tensor(xTest)
loss_func = tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True)
perturbations = get_prtbtns(xTest_tensor, yTest, loss_func, baseModel)
```

```
def FGS_untargeted_attack(X, label, model, eps=1):
    newX = np.zeros((X.shape[0], X.shape[1], X.shape[2]))

    for i in range(X.shape[0]):
      newX[i] = X[i] + e/255.0 * perturbations[i]
    newX = tf.clip_by_value(newX, 0, 1)
    return newX
```

Q3: Calculate the fraction of test images that were correctly classified by the baseline DNN that are mis-classified after adversarial perturbation, as a function of ϵ, and plot the result.

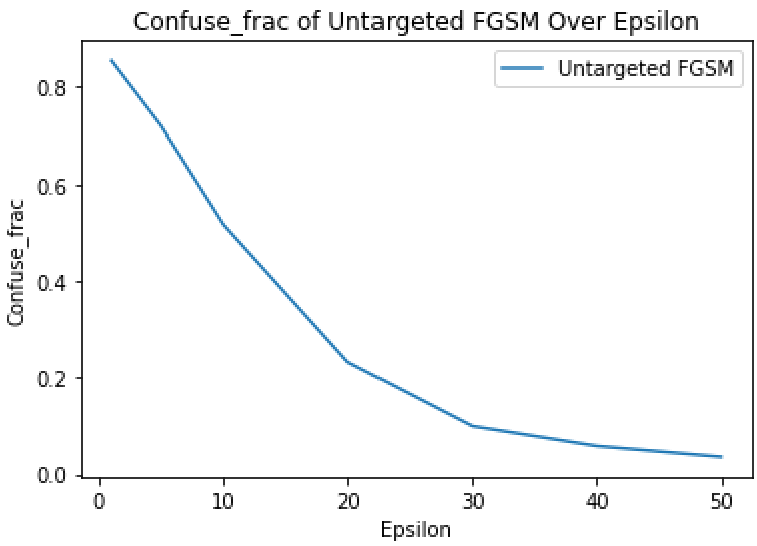
```
epss = [1, 5, 10, 20, 30, 40, 50]
rpt = pd.DataFrame(index=epss, columns=['Confuse_frac'])

for e in epss:
    xTestAftAttack = FGS_untargeted_attack(xTest, yTest, baseModel, eps=e)

    loss, acc = baseModel.evaluate(x=xTestAftAttack, y=yTest, verbose=0)
    rpt.loc[e, 'Confuse_frac'] = acc

```

```
plt.plot(epss, rpt['Confuse_frac'], label = "Untargeted FGSM")
plt.xlabel('Epsilon')
plt.ylabel('Confuse_frac')
plt.title('Confuse_frac of Untargeted FGSM Over Epsilon')
plt.legend()
plt.show()
```



FGSM based targeted attacks

Q4: Implement FGS targetd attack

```
yTest_target = (yTest + 1) % 10

xTest_tensor = tf.convert_to_tensor(xTest)
loss_func = tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True)
perturbations_target = get_prtbtns(xTest_tensor, yTest_target, loss_func, baseMo
```

```
def FGS_targeted_attack(X, label, model, eps=1):
    newX = np.zeros((X.shape[0], X.shape[1], X.shape[2]))

    for i in range(X.shape[0]):
      newX[i] = X[i] - e/255.0 * perturbations_target[i]
    newX = tf.clip_by_value(newX, 0, 1)
    return newX
```

Q5:Report the attack's success rate as a function of parameter ϵ where success rate is defined as the fraction of test images that were correctly classified by the baseline DNN that are mis-classified after adversarial perturbations with label (i+1)%10.

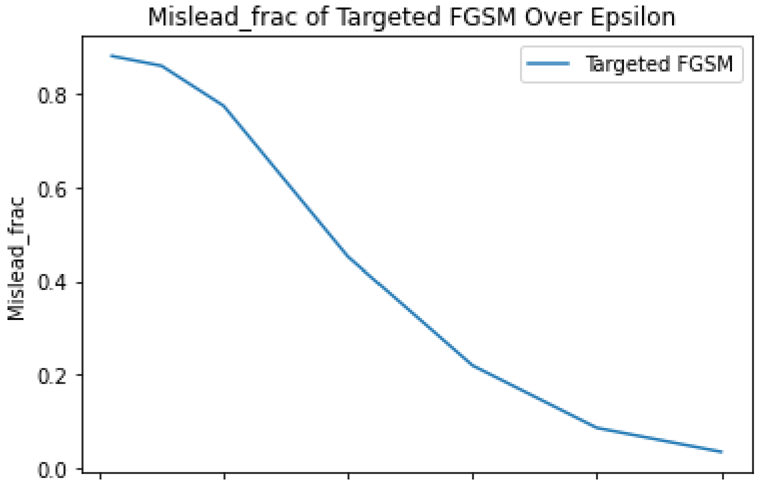
```
epss = [1, 5, 10, 20, 30, 40, 50]
rpt = pd.DataFrame(index=epss, columns=['Mislead_frac'])

for e in epss:
    xTestAftAttack = FGS_targeted_attack(xTest, yTest_target, baseModel, eps=e)

    loss, acc = baseModel.evaluate(x=xTestAftAttack, y=yTest, verbose=0)
    rpt.loc[e, 'Mislead_frac'] = acc
rpt
```

	Mislead_frac
1	0.88
5	0.859
10	0.7734
20	0.4515
30	0.2198
40	0.0866
50	0.0354

```
plt.plot(epss, rpt['Mislead_frac'], label = "Targeted FGSM")
plt.xlabel('Epsilon')
plt.ylabel('Mislead_frac')
plt.title('Mislead_frac of Targeted FGSM Over Epsilon ')
plt.legend()
plt.show()
```



Adversarial Retraining against Untargeted FGSM Attacks:

Q6: Append the adversarially perturbed images to training set, but using their correct labels.

```
e = 10
loss_func = tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True)

def attack_train(X, train_target, model, eps=10):
    newX = np.zeros((X.shape[0], X.shape[1], X.shape[2]))
    for i in range(X.shape[0]):
      newX[i] = X[i] + e/255.0 * train_target[i]
    newX = tf.clip_by_value(newX, 0, 1)
    return newX

xTrain_tensor = tf.convert_to_tensor(xTrain)
perturbations_train_target = get_prtbtns(xTrain_tensor, yTrain, loss_func, baseM
xTrain_AftAttack = attack_train(xTrain, perturbations_train_target, baseModel, e
```

```
newX = np.concatenate((xTrain, xTrain_AftAttack), axis=0)
newY = np.concatenate((yTrain, yTrain), axis=0)
```

```
advModel = tf.keras.models.Sequential([
    tf.keras.layers.Flatten(input_shape=(28, 28)),
    tf.keras.layers.Dense(128, activation='relu'),
    tf.keras.layers.Dropout(0.2),
    tf.keras.layers.Dense(10)
])
advModel.compile(optimizer='adam',
              loss=tf.keras.losses.SparseCategoricalCrossentropy(from_logits=Tru
              metrics=['accuracy'])
advModel.fit(newX, newY, epochs=10)
```

```
Epoch 1/10
3750/3750 [==============================] - 9s 2ms/step - loss: 0.4575 - accu
Epoch 2/10
3750/3750 [==============================] - 9s 2ms/step - loss: 0.3103 - accu
Epoch 3/10
```

```
3750/3750 [==============================] - 9s 2ms/step - loss: 0.2660 - accu
Epoch 4/10
3750/3750 [==============================] - 9s 2ms/step - loss: 0.2451 - accu
Epoch 5/10
3750/3750 [==============================] - 9s 2ms/step - loss: 0.2247 - accu
Epoch 6/10
3750/3750 [==============================] - 9s 2ms/step - loss: 0.2123 - accu
Epoch 7/10
3750/3750 [==============================] - 9s 2ms/step - loss: 0.2031 - accu
Epoch 8/10
3750/3750 [==============================] - 9s 2ms/step - loss: 0.1912 - accu
Epoch 9/10
3750/3750 [==============================] - 9s 2ms/step - loss: 0.1867 - accu
Epoch 10/10
3750/3750 [==============================] - 9s 2ms/step - loss: 0.1812 - accu
<keras.callbacks.History at 0x7f30140b8450>
```

Q7: Report the classification accuracy of the adversarially retrained DNN on the original test dataset that contains only clean inputs. Implement FGSM based untargeted attacks using images from the clean test set on the adversarially retrained DNN. Report the success rate of your attack. Is the adversarially retrained DNN robust against adversarial perturbations?

```
new_loss, new_acc = advModel.evaluate(x=xTest, y=yTest, verbose=0)
print("The new accuracy for clean test input: ", new_acc)
```

```
The new accuracy for clean test input:  0.8755000233650208
```

```
e=10
perturbations = get_prtbtns(xTest_tensor, yTest, loss_func, advModel)
xTestAftAttack = FGS_untargeted_attack(xTest, yTest, advModel, eps=e)
new_attack_loss, new_attack_acc = advModel.evaluate(x=xTestAftAttack, y=yTest, v
print("The new accuracy for untargeted attack input: ", new_attack_acc)
# costPerPixel = # Your Code
```

```
The new accuracy for untargeted attack input:  0.7906000018119812
```

Challenge

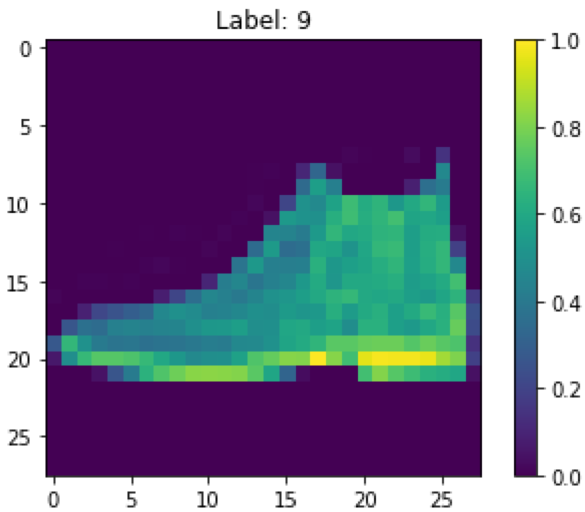
In this section, I'm going to try IFGSM.

```
eps = 5 / 255.0
steps = 20
step_alpha = 0.005
```

```
def IFGS_untargeted_attack(x, y, loss_func, model):
    perturbation = np.zeros(x.shape)
    for step in range(steps):
        with tf.GradientTape() as gt:
            gt.watch(x)
```

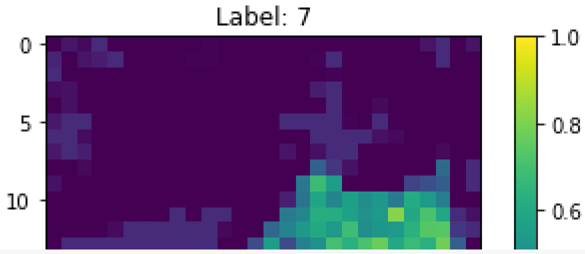
```
            p = model(x)
            loss = loss_func(y, p)
        grad = gt.gradient(loss, x)
        perturbation = tf.sign(grad)
        x += step_alpha * perturbation
        x = tf.clip_by_value(x, 0, 1)
    x +=  eps * perturbation
    x = tf.clip_by_value(x, 0, 1)
    # print(x)
    return x
```

```
# Plot picture
plt.figure()
plt.imshow(xTest[0])
plt.title('Label: {}'.format(yTest[0]))
plt.colorbar()
plt.grid(False)
plt.show()
```




```
xTest_tensor = tf.convert_to_tensor(xTest)
loss_func = tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True)
new_img = IFGS_untargeted_attack(xTest_tensor[0:1], yTest[0], loss_func, baseMod
```

```
new_y = tf.argmax(baseModel(new_img)[0])
plt.figure()
plt.imshow(new_img[0])
plt.title('Label: {}'.format(new_y))
plt.colorbar()
plt.grid(False)
plt.show()
```




```
save_new_img = np.array(new_img)[0]*255
# ssave_new_img = save_new_img.astype(int)
```

```
from PIL import Image
im = Image.fromarray(save_new_img)
im.convert('RGB').save("Challenge_picture.jpeg")
```

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