EECE680C Neural Networks & Deep Learning

Homework 2

Due: Thursday, March 11, 2021

1. Python & Tensorflow programming. Design and train CNN over the MNIST dataset. You can use our sample code or design new network of your own.
    a. After training, please plot 10 sample images (one for each of 10 digits) that are correctly classified, and 10 sample images (one for each of 10 digits) that are wrongly classified (please print which digit the CNN classifies it to). You can pick the images from either the training dataset or the test dataset.
    b. Please plot the learning curve and the test (generalization) curve together as functions of epochs. The first curve shows the change of the loss function (or the accuracy function) over the training dataset, while the second curve shows the change of the loss function (or the accuracy function) over the test dataset. Can you find any underfit or overfit problem in your figure?

Please put your code and the results into a pdf file and upload to blackboard.

Solution:

```
import tensorflow as tf

mnist = tf.keras.datasets.mnist
(x_train, y_train), (x_test , y_test) = mnist.load_data()
x_train, x_test = x_train / 255.0, x_test / 255.0
x_train = tf.expand_dims(x_train, axis=-1)
x_test = tf.expand_dims(x_test, axis=-1)
print('Train: X=%s, y=%s' % (x_train.shape, y_train.shape))
print('Test: X=%s, y=%s' % (x_test.shape, y_test.shape))
```

```
Train: X=(60000, 28, 28, 1), y=(60000,)
Test: X=(10000, 28, 28, 1), y=(10000,)
```

```
model = tf.keras.models.Sequential([
  tf.keras.layers.Conv2D(32, (3, 3), activation='relu', kernel_initializer
='he_uniform', input_shape=(28, 28, 1)),
  tf.keras.layers.MaxPooling2D((2, 2)),
  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)
])
predictions = model(x_train[:1]).numpy()
predictions
```

```
array([[ 0.45140648,  0.8669158 , -0.24890845, -0.1515798 , -0.6078398 ,
         1.6573017 ,  0.05001862,  1.850287  , -0.34007734, -0.37011233]],
        dtype=float32
```

```
tf.nn.softmax(predictions).numpy()
```

```
array([[0.07777139, 0.11783472, 0.03860797, 0.04255457, 0.02696466,
        0.2597368 , 0.05205942, 0.31502566, 0.03524381, 0.03420099]],
        dtype=float32)
```

```
loss_fn = tf.keras.losses.SparseCategoricalCrossentropy(from_logits=True)
loss_fn(y_train[:1], predictions).numpy()
```

```
   1.3480865
```

```
model.compile(optimizer='adam',
              loss=loss_fn,
              metrics=['accuracy'])
```

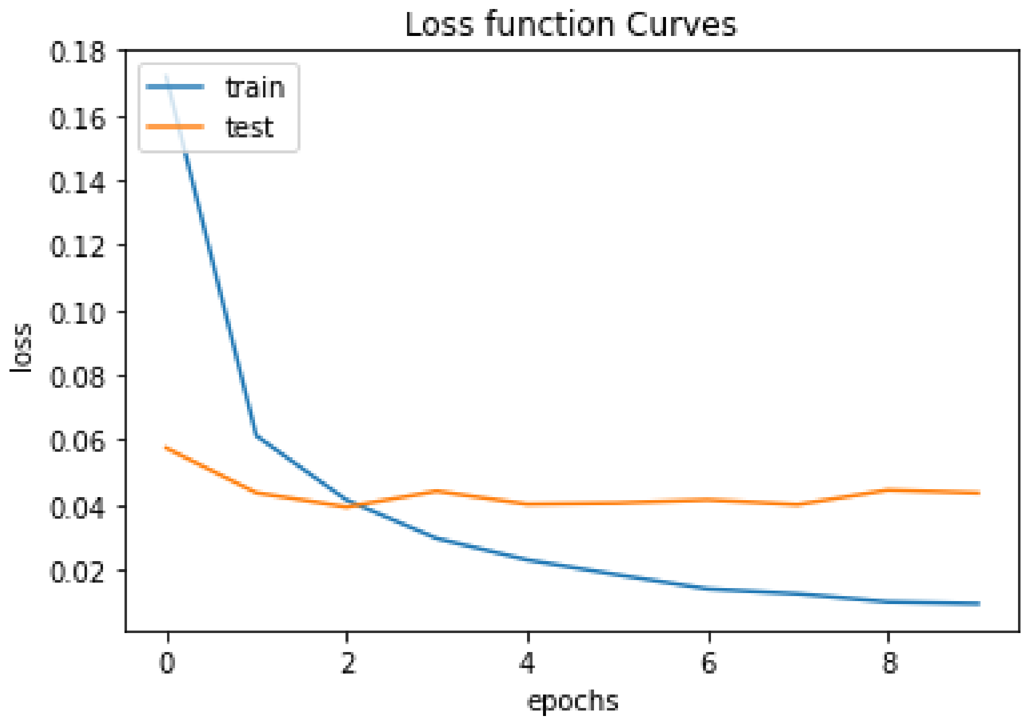
```
history = model.fit(x_train, y_train,validation_data=(x_test,y_test),epoch
s=10)
```

```
Epoch 1/10
1875/1875 [==============================] - 37s 19ms/step - loss: 0.3258
- accuracy: 0.9004 - val_loss: 0.0574 - val_accuracy: 0.9824
Epoch 2/10
1875/1875 [==============================] - 37s 20ms/step - loss: 0.0641
- accuracy: 0.9808 - val_loss: 0.0436 - val_accuracy: 0.9854
Epoch 3/10
1875/1875 [==============================] - 36s 19ms/step - loss: 0.0392
- accuracy: 0.9874 - val_loss: 0.0392 - val_accuracy: 0.9860
Epoch 4/10
1875/1875 [==============================] - 36s 19ms/step - loss: 0.0275
- accuracy: 0.9905 - val_loss: 0.0441 - val_accuracy: 0.9857
Epoch 5/10
```

```
1875/1875 [==============================] - 36s 19ms/step - loss: 0.0220
- accuracy: 0.9923 - val_loss: 0.0401 - val_accuracy: 0.9882
Epoch 6/10
1875/1875 [==============================] - 36s 19ms/step - loss: 0.0169
- accuracy: 0.9942 - val_loss: 0.0404 - val_accuracy: 0.9887
Epoch 7/10
1875/1875 [==============================] - 36s 19ms/step - loss: 0.0127
- accuracy: 0.9955 - val_loss: 0.0414 - val_accuracy: 0.9873
Epoch 8/10
1875/1875 [==============================] - 36s 19ms/step - loss: 0.0108
- accuracy: 0.9961 - val_loss: 0.0400 - val_accuracy: 0.9881
Epoch 9/10
1875/1875 [==============================] - 36s 19ms/step - loss: 0.0105
- accuracy: 0.9965 - val_loss: 0.0445 - val_accuracy: 0.9885
Epoch 10/10
   1875/1875 [==============================] - 37s 20ms/step - loss: 0.0087
   - accuracy: 0.9971 - val_loss: 0.0436 - val_accuracy: 0.9884
```

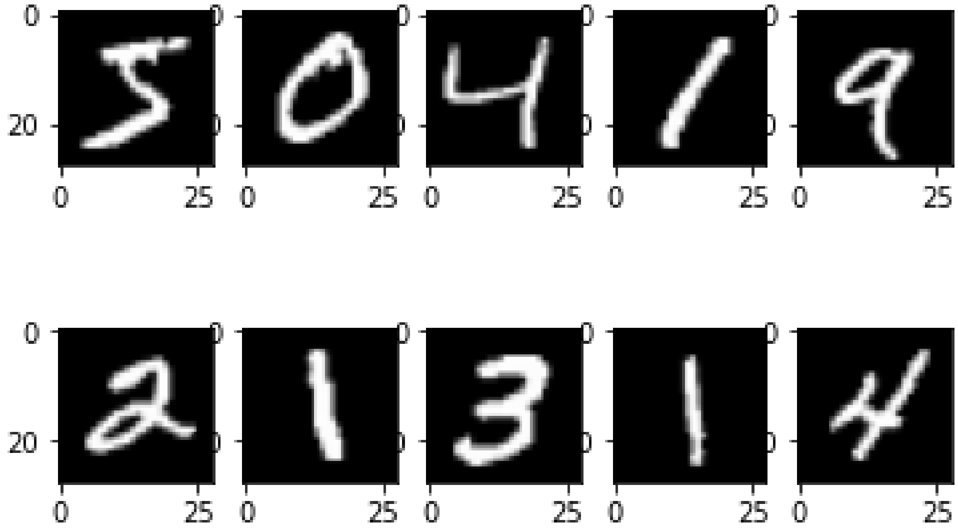
```python
import matplotlib.pyplot as plt
print(history.history.keys())
plt.plot(history.history['loss'])
plt.plot(history.history['val_loss'])
plt.title('Loss function Curves')
plt.ylabel('loss')
plt.xlabel('epochs')
plt.legend(['train','test'], loc='upper left')
plt.show()
```

```
   dict_keys(['loss', 'accuracy', 'val_loss', 'val_accuracy'])
```

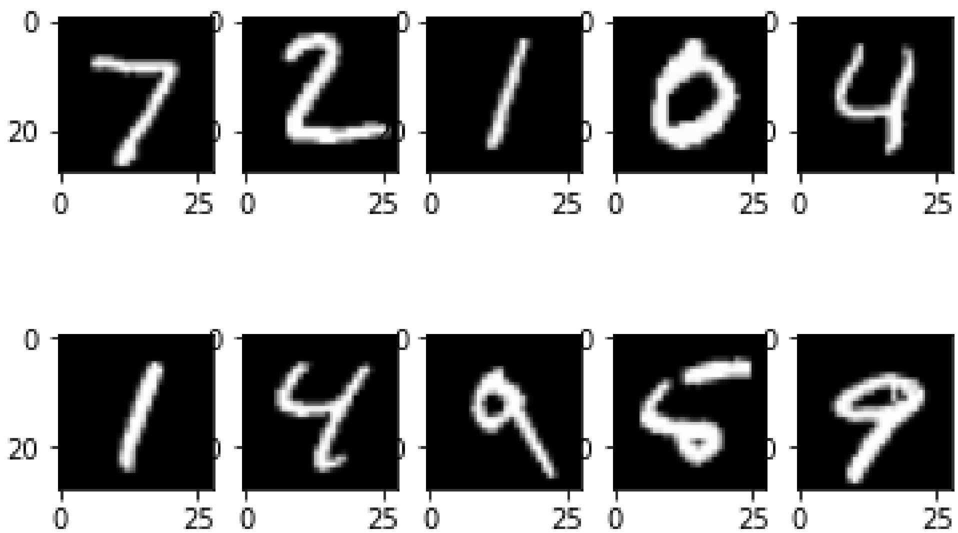


(b) Here no particular problem of underfit or overfit is found. The training and testing data converges at a close range.

```
for i in range(10):
  x_train=tf.squeeze(x_train)
  pyplot.subplot(2,5, i+1)
  # plot raw pixel data
  pyplot.imshow(x_train[i], cmap=pyplot.get_cmap('gray'))
# show the figure
pyplot.show()
```




```python
for i in range(10):
  x_test=tf.squeeze(x_test)
  pyplot.subplot(2,5, i+1)
  # plot raw pixel data
  pyplot.imshow(x_test[i], cmap=pyplot.get_cmap('gray'))
# show the figure
pyplot.show()
```



(a) Here we plotted the first 10 images of training and testing datasets.