# CS156 (Introduction to AI), Spring 2022

## Homework 9 submission

Roster Name: Bernard Tan

Preferred Name (if different): Bernard

Student ID: 015215317

Email address: bernard.tan@sjsu.edu

Any special notes or anything you would like to communicate to me about this homework submission goes in here.

## References and sources

List all your references and sources here. This includes all sites/discussion boards/blogs/posts/etc. where you grabbed some code examples.

## Solution

### Load libraries and set random number generator seed

```
import tensorflow
from tensorflow import keras
from tensorflow.keras.layers import BatchNormalization
from tensorflow.keras.layers import Conv2D
from tensorflow.keras.layers import Conv2DTranspose
from tensorflow.keras.layers import LeakyReLU
from tensorflow.keras.layers import Activation
from tensorflow.keras.layers import Flatten
from tensorflow.keras.layers import Dense
from tensorflow.keras.layers import Reshape
from tensorflow.keras.layers import Input
from tensorflow.keras.models import Model
from tensorflow.keras import backend as K
import numpy as np
```

```
from tensorflow.keras.layers import Dense, Input, Conv2D, LSTM, MaxPool2D, UpSampling2D
from sklearn.model_selection import train_test_split
from tensorflow.keras.callbacks import EarlyStopping
from tensorflow.keras.utils import to_categorical
from numpy import argmax, array_equal
import matplotlib.pyplot as plt
import seaborn as sns
from tensorflow.keras.models import Model
from random import randint
import pandas as pd
import numpy as np
from tensorflow.keras import layers
from PIL import Image
from tensorflow.keras import regularizers
from tensorflow.keras import backend
from datetime import datetime


np.random.seed(42)


input_shape = (28, 28, 1)

# the data, split between train and test sets
(x_train_valid, y_train_valid), (x_test, y_test) = keras.datasets.fashion_mnist.load_data()
x_train, x_validation, y_train, y_validation = train_test_split(x_train_valid, y_train_valid,

# Scale images to the [0, 1] range
x_train = x_train.astype("float32") / 255
x_validation = x_validation.astype("float32") / 255
x_test = x_test.astype("float32") / 255

x_train.shape, x_validation.shape, x_test.shape
```

```
((48000, 28, 28), (12000, 28, 28), (10000, 28, 28))
```

```
# Reshape the images into flat ANN layers
x_train = x_train.reshape(-1, 784)
x_validation = x_validation.reshape(-1, 784)
x_test = x_test.reshape(-1, 784)

x_train.shape, x_validation.shape, x_test.shape
```

```
((48000, 784), (12000, 784), (10000, 784))
```

```
## input layer
# 28*28
input_layer = Input(shape=(784,))

## encoding architecture
encode_layer1 = Dense(128, activation='relu')(input_layer)
```

```
encode_layer2 = Dense(64, activation='relu')(encode_layer1)
encode_layer3 = Dense(32, activation='relu')(encode_layer2)

## decoding architecture
decode_layer1 = Dense(64, activation='relu')(encode_layer3)
decode_layer2 = Dense(128, activation='relu')(decode_layer1)
decode_layer3 = Dense(784, activation='relu')(decode_layer2)

model = Model(input_layer, decode_layer3)
model.summary()
```

```
Model: "model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 784)]             0
_________________________________________________________________
dense (Dense)                (None, 128)               100480
_________________________________________________________________
dense_1 (Dense)              (None, 64)                8256
_________________________________________________________________
dense_2 (Dense)              (None, 32)                2080
_________________________________________________________________
dense_3 (Dense)              (None, 64)                2112
_________________________________________________________________
dense_4 (Dense)              (None, 128)               8320
_________________________________________________________________
dense_5 (Dense)              (None, 784)               101136
=================================================================
Total params: 222,384
Trainable params: 222,384
Non-trainable params: 0
_________________________________________________________________
```

```
model.compile(optimizer='adam', loss='mse')
early_stopping = EarlyStopping(monitor='val_loss', min_delta=0, patience=10, verbose=1, mode=
model.fit(x_train, x_train, epochs=30, batch_size=2048, validation_data=(x_validation, x_vali
```

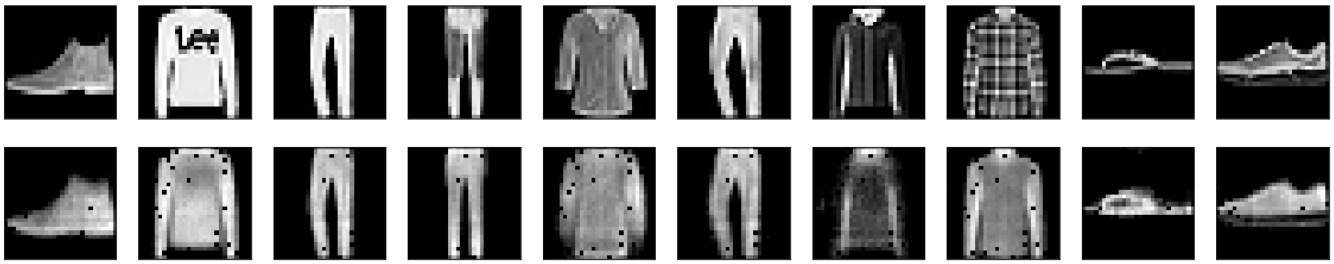
```
24/24 [==============================] - 1s 24ms/step - loss: 0.0781 - val_loss: 0.06
Epoch 3/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0619 - val_loss: 0.05
Epoch 4/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0476 - val_loss: 0.04
Epoch 5/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0391 - val_loss: 0.03
Epoch 6/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0340 - val_loss: 0.03
Epoch 7/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0315 - val_loss: 0.03
Epoch 8/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0300 - val_loss: 0.02
Epoch 9/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0290 - val_loss: 0.02
Epoch 10/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0282 - val_loss: 0.02
```

```
24/24 [==============================] - 1s 25ms/step - loss: 0.0282 - val_loss: 0.02
Epoch 11/30
24/24 [==============================] - 1s 24ms/step - loss: 0.0275 - val_loss: 0.02
Epoch 12/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0269 - val_loss: 0.02
Epoch 13/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0263 - val_loss: 0.02
Epoch 14/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0257 - val_loss: 0.02
Epoch 15/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0252 - val_loss: 0.02
Epoch 16/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0248 - val_loss: 0.024
Epoch 17/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0246 - val_loss: 0.024
Epoch 18/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0243 - val_loss: 0.024
Epoch 19/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0241 - val_loss: 0.024
Epoch 20/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0239 - val_loss: 0.024
Epoch 21/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0237 - val_loss: 0.02
Epoch 22/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0234 - val_loss: 0.02
Epoch 23/30
24/24 [==============================] - 1s 24ms/step - loss: 0.0230 - val_loss: 0.02
Epoch 24/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0228 - val_loss: 0.02
Epoch 25/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0226 - val_loss: 0.02
Epoch 26/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0225 - val_loss: 0.02
Epoch 27/30
24/24 [==============================] - 1s 26ms/step - loss: 0.0223 - val_loss: 0.02
Epoch 28/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0222 - val_loss: 0.02
Epoch 29/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0220 - val_loss: 0.02
Epoch 30/30
24/24 [==============================] - 1s 25ms/step - loss: 0.0220 - val_loss: 0.02
<keras.callbacks.History at 0x7fb117c21850>
```

```
predictions = model.predict(x_test)
n = 10
plt.figure(figsize=(20, 4))
for i in range(n):
    # original
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

    # reconstruction
```

```
        ax = plt.subplot(2, n, i + 1 + n)
        plt.imshow(predictions[i].reshape(28, 28))
        plt.gray()
        ax.get_xaxis().set_visible(False)
        ax.get_yaxis().set_visible(False)
    plt.show()
```



```
input_shape = (28, 28, 1)

# the data, split between train and test sets
(x_train_valid, y_train_valid), (x_test, y_test) = keras.datasets.fashion_mnist.load_data()
x_train, x_validation, y_train, y_validation = train_test_split(x_train_valid, y_train_valid,

# Scale images to the [0, 1] range
x_train = x_train.astype("float32") / 255
x_validation = x_validation.astype("float32") / 255
x_test = x_test.astype("float32") / 255

x_train.shape, x_validation.shape, x_test.shape
```

```
((48000, 28, 28), (12000, 28, 28), (10000, 28, 28))
```

```
# shape back into image matrices
x_train = x_train.reshape(-1, 28, 28, 1)
x_validation = x_validation.reshape(-1, 28, 28, 1)
x_test = x_test.reshape(-1, 28, 28, 1)

x_train.shape, x_validation.shape, x_test.shape
```

```
((48000, 28, 28, 1), (12000, 28, 28, 1), (10000, 28, 28, 1))
```

```
noise_factor = 0.4
x_train_noisy = x_train + noise_factor * np.random.normal(loc=0.0, scale=1.0, size=x_train.sh
x_validation_noisy = x_validation + noise_factor * np.random.normal(loc=0.0, scale=1.0, size=
x_test_noisy = x_test + noise_factor * np.random.normal(loc=0.0, scale=1.0, size=x_test.shape
```

```
x_train_noisy = np.clip(x_train_noisy, 0., 1.)
x_validation_noisy = np.clip(x_validation_noisy, 0., 1.)
x_test_noisy = np.clip(x_test_noisy, 0., 1.)


input_layer = keras.Input(shape=(28, 28, 1))

x = layers.Conv2D(32, (3, 3), activation='relu', padding='same')(input_layer)
x = layers.MaxPooling2D((2, 2), padding='same')(x)
x = layers.Conv2D(32, (3, 3), activation='relu', padding='same')(x)
encoded = layers.MaxPooling2D((2, 2), padding='same')(x)

# At this point the representation is (7, 7, 32)

x = layers.Conv2D(32, (3, 3), activation='relu', padding='same')(encoded)
x = layers.UpSampling2D((2, 2))(x)
x = layers.Conv2D(32, (3, 3), activation='relu', padding='same')(x)
x = layers.UpSampling2D((2, 2))(x)
decoded = layers.Conv2D(1, (3, 3), activation='sigmoid', padding='same')(x)

autoencoder = keras.Model(input_layer, decoded)
autoencoder.compile(optimizer='adam', loss='binary_crossentropy')

autoencoder.summary()
```

```
Model: "model_1"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_2 (InputLayer)         [(None, 28, 28, 1)]       0
_________________________________________________________________
conv2d (Conv2D)              (None, 28, 28, 32)        320
_________________________________________________________________
max_pooling2d (MaxPooling2D) (None, 14, 14, 32)        0
_________________________________________________________________
conv2d_1 (Conv2D)            (None, 14, 14, 32)        9248
_________________________________________________________________
max_pooling2d_1 (MaxPooling2 (None, 7, 7, 32)          0
_________________________________________________________________
conv2d_2 (Conv2D)            (None, 7, 7, 32)          9248
_________________________________________________________________
up_sampling2d (UpSampling2D) (None, 14, 14, 32)        0
_________________________________________________________________
conv2d_3 (Conv2D)            (None, 14, 14, 32)        9248
_________________________________________________________________
up_sampling2d_1 (UpSampling2 (None, 28, 28, 32)        0
_________________________________________________________________
conv2d_4 (Conv2D)            (None, 28, 28, 1)         289
=================================================================
Total params: 28,353
Trainable params: 28,353
Non-trainable params: 0
_________________________________________________________________
```

```
autoencoder.fit(x_train_noisy, x_train,
                epochs=30,
                batch_size=2048,
                shuffle=True,
                validation_data=(x_validation_noisy, x_validation))
```

```
24/24 [==============================] - 38s 2s/step - loss: 0.3628 - val_loss: 0.344
Epoch 3/30
24/24 [==============================] - 38s 2s/step - loss: 0.3353 - val_loss: 0.326
Epoch 4/30
24/24 [==============================] - 38s 2s/step - loss: 0.3223 - val_loss: 0.318
Epoch 5/30
24/24 [==============================] - 38s 2s/step - loss: 0.3164 - val_loss: 0.314
Epoch 6/30
24/24 [==============================] - 38s 2s/step - loss: 0.3129 - val_loss: 0.311
Epoch 7/30
24/24 [==============================] - 37s 2s/step - loss: 0.3104 - val_loss: 0.309
Epoch 8/30
24/24 [==============================] - 39s 2s/step - loss: 0.3087 - val_loss: 0.307
Epoch 9/30
24/24 [==============================] - 38s 2s/step - loss: 0.3069 - val_loss: 0.305
Epoch 10/30
24/24 [==============================] - 38s 2s/step - loss: 0.3058 - val_loss: 0.304
Epoch 11/30
24/24 [==============================] - 38s 2s/step - loss: 0.3048 - val_loss: 0.304
Epoch 12/30
24/24 [==============================] - 38s 2s/step - loss: 0.3037 - val_loss: 0.302
Epoch 13/30
24/24 [==============================] - 38s 2s/step - loss: 0.3030 - val_loss: 0.302
Epoch 14/30
24/24 [==============================] - 38s 2s/step - loss: 0.3021 - val_loss: 0.301
Epoch 15/30
24/24 [==============================] - 38s 2s/step - loss: 0.3017 - val_loss: 0.301
Epoch 16/30
24/24 [==============================] - 37s 2s/step - loss: 0.3010 - val_loss: 0.300
Epoch 17/30
24/24 [==============================] - 37s 2s/step - loss: 0.3002 - val_loss: 0.299
Epoch 18/30
24/24 [==============================] - 37s 2s/step - loss: 0.3005 - val_loss: 0.299
Epoch 19/30
24/24 [==============================] - 37s 2s/step - loss: 0.2999 - val_loss: 0.299
Epoch 20/30
24/24 [==============================] - 37s 2s/step - loss: 0.2987 - val_loss: 0.298
Epoch 21/30
24/24 [==============================] - 37s 2s/step - loss: 0.2983 - val_loss: 0.297
Epoch 22/30
24/24 [==============================] - 37s 2s/step - loss: 0.2978 - val_loss: 0.297
Epoch 23/30
24/24 [==============================] - 37s 2s/step - loss: 0.2976 - val_loss: 0.297
Epoch 24/30
24/24 [==============================] - 37s 2s/step - loss: 0.2971 - val_loss: 0.296
Epoch 25/30
24/24 [==============================] - 38s 2s/step - loss: 0.2967 - val_loss: 0.296
Epoch 26/30
24/24 [==============================] - 38s 2s/step - loss: 0.2965 - val_loss: 0.295
Epoch 27/30
```

```
Epoch 27/30
24/24 [==============================] - 37s 2s/step - loss: 0.2960 - val_loss: 0.295
Epoch 28/30
24/24 [==============================] - 37s 2s/step - loss: 0.2959 - val_loss: 0.295
Epoch 29/30
24/24 [==============================] - 38s 2s/step - loss: 0.2957 - val_loss: 0.295
Epoch 30/30
24/24 [==============================] - 38s 2s/step - loss: 0.2951 - val_loss: 0.294
<keras.callbacks.History at 0x7fb0fd717610>
```

```
predictions = autoencoder.predict(x_test)

n = 10
plt.figure(figsize=(20, 4))
for i in range(n):
    # noisy
    ax = plt.subplot(2, n, i + 1)
    plt.imshow(x_test_noisy[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)

    # reconstruction
    ax = plt.subplot(2, n, i + 1 + n)
    plt.imshow(predictions[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
plt.show()
```