Andrew Vu - CS156_HW9_GPU

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1 CS156 (Introduction to AI), Spring 2022

2 Homework 9 submission

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

2.1 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.

- Autoencoders file

2.2 Solution

Load libraries and set random number generator seed

[64]:
```
import numpy as np
import tensorflow as tf
from tensorflow import keras
from sklearn.model_selection import train_test_split

from tensorflow.keras import layers
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

import matplotlib.pyplot as plt
```

[65]:
```
np.random.seed(42)
```

Code the solution

2.2.1 Load and prepare image data

[66]:
```
(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, test_size=0.2, random_state=0)

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
# scale images to the [0,1] range
```

[66]:
```
((48000, 28, 28), (12000, 28, 28), (10000, 28, 28))
```

2.2.2 Autoencoder model and its performance for first 10 images in test set

[67]:
```
# Reshape 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
```

[67]:
```
((48000, 784), (12000, 784), (10000, 784))
```

[68]:
```
input_layer = Input(shape=(784,)) # 28 * 28
encoded = layers.Dense(128, activation='relu')(input_layer)
encoded = layers.Dense(64, activation='relu')(encoded)
encoded = layers.Dense(32, activation='relu')(encoded)

decoded = layers.Dense(64, activation='sigmoid')(encoded)
decoded = layers.Dense(128, activation='sigmoid')(decoded)
decoded = layers.Dense(784, activation='sigmoid')(decoded)

# reconstruction model:
autoencoder = keras.Model(input_layer, decoded)
autoencoder.summary()

# encoder model
encoder = keras.Model(input_layer, encoded)

# decoder model:
encoded_input = keras.Input(shape=(128,))
decoder_layer = autoencoder.layers[-1]  # last layer of autoencoder model
```

```
decoder = keras.Model(encoded_input, decoder_layer(encoded_input))
```

```
Model: "functional_57"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_16 (InputLayer)        [(None, 784)]             0
_________________________________________________________________
dense_30 (Dense)             (None, 128)               100480
_________________________________________________________________
dense_31 (Dense)             (None, 64)                8256
_________________________________________________________________
dense_32 (Dense)             (None, 32)                2080
_________________________________________________________________
dense_33 (Dense)             (None, 64)                2112
_________________________________________________________________
dense_34 (Dense)             (None, 128)               8320
_________________________________________________________________
dense_35 (Dense)             (None, 784)               101136
=================================================================
Total params: 222,384
Trainable params: 222,384
Non-trainable params: 0
_________________________________________________________________
```

[69]:
```
# Fitting/training the model

autoencoder.compile(optimizer='adam', loss='binary_crossentropy')

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

```
Epoch 1/30
24/24 [==============================] - 1s 42ms/step - loss: 0.5879 - val_loss:
0.5141
Epoch 2/30
24/24 [==============================] - 1s 37ms/step - loss: 0.4989 - val_loss:
0.4915
Epoch 3/30
24/24 [==============================] - 1s 41ms/step - loss: 0.4867 - val_loss:
0.4828
Epoch 4/30
24/24 [==============================] - 1s 46ms/step - loss: 0.4747 - val_loss:
0.4646
Epoch 5/30
```

```
24/24 [==============================] - 1s 46ms/step - loss: 0.4506 - val_loss:
0.4371
Epoch 6/30
24/24 [==============================] - 1s 47ms/step - loss: 0.4261 - val_loss:
0.4161
Epoch 7/30
24/24 [==============================] - 1s 40ms/step - loss: 0.4075 - val_loss:
0.4020
Epoch 8/30
24/24 [==============================] - 1s 41ms/step - loss: 0.3966 - val_loss:
0.3937
Epoch 9/30
24/24 [==============================] - 1s 40ms/step - loss: 0.3895 - val_loss:
0.3892
Epoch 10/30
24/24 [==============================] - 1s 42ms/step - loss: 0.3859 - val_loss:
0.3850
Epoch 11/30
24/24 [==============================] - 1s 44ms/step - loss: 0.3818 - val_loss:
0.3815
Epoch 12/30
24/24 [==============================] - 1s 39ms/step - loss: 0.3784 - val_loss:
0.3785
Epoch 13/30
24/24 [==============================] - 1s 38ms/step - loss: 0.3756 - val_loss:
0.3753
Epoch 14/30
24/24 [==============================] - 1s 39ms/step - loss: 0.3720 - val_loss:
0.3714
Epoch 15/30
24/24 [==============================] - 1s 40ms/step - loss: 0.3683 - val_loss:
0.3673
Epoch 16/30
24/24 [==============================] - 1s 39ms/step - loss: 0.3638 - val_loss:
0.3629
Epoch 17/30
24/24 [==============================] - 1s 37ms/step - loss: 0.3599 - val_loss:
0.3592
Epoch 18/30
24/24 [==============================] - 1s 37ms/step - loss: 0.3562 - val_loss:
0.3564
Epoch 19/30
24/24 [==============================] - 1s 37ms/step - loss: 0.3535 - val_loss:
0.3540
Epoch 20/30
24/24 [==============================] - 1s 37ms/step - loss: 0.3510 - val_loss:
0.3518
Epoch 21/30
```

```
24/24 [==============================] - 1s 37ms/step - loss: 0.3493 - val_loss:
0.3493
Epoch 22/30
24/24 [==============================] - 1s 36ms/step - loss: 0.3473 - val_loss:
0.3479
Epoch 23/30
24/24 [==============================] - 1s 36ms/step - loss: 0.3455 - val_loss:
0.3464
Epoch 24/30
24/24 [==============================] - 1s 37ms/step - loss: 0.3447 - val_loss:
0.3453
Epoch 25/30
24/24 [==============================] - 1s 37ms/step - loss: 0.3430 - val_loss:
0.3436
Epoch 26/30
24/24 [==============================] - 1s 37ms/step - loss: 0.3414 - val_loss:
0.3422
Epoch 27/30
24/24 [==============================] - 1s 37ms/step - loss: 0.3407 - val_loss:
0.3416
Epoch 28/30
24/24 [==============================] - 1s 38ms/step - loss: 0.3391 - val_loss:
0.3399
Epoch 29/30
24/24 [==============================] - 1s 37ms/step - loss: 0.3378 - val_loss:
0.3387
Epoch 30/30
24/24 [==============================] - 1s 36ms/step - loss: 0.3367 - val_loss:
0.3380
```

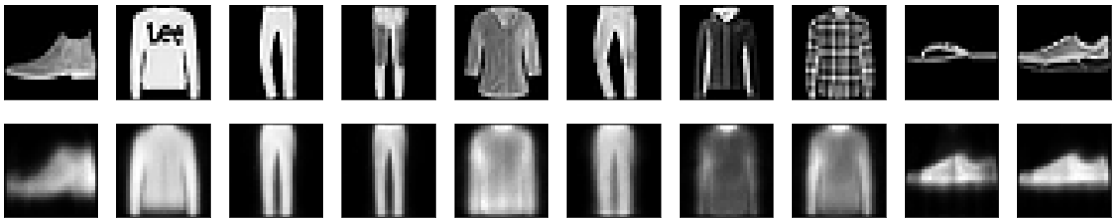
[69]:
```
<tensorflow.python.keras.callbacks.History at 0x21820f4edd8>
```

[70]:
```
# Plotting the reconstructed images
predictions = autoencoder.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()
```



2.2.3 Reshape + denoise images with an autoencoder model + plotting

[71]:
```
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
```

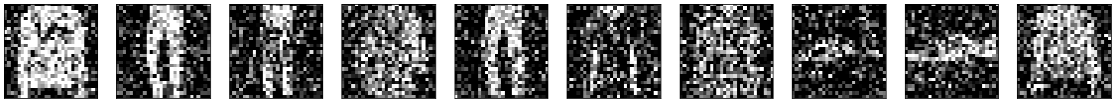
[71]:
```
((48000, 28, 28, 1), (12000, 28, 28, 1), (10000, 28, 28, 1))
```

[72]:
```
noise_factor = 0.4
x_train_noisy = x_train + noise_factor * np.random.normal(loc=0.0, scale=1.0,␣
 ↪size=x_train.shape)
x_validation_noisy = x_validation + noise_factor * np.random.normal(loc=0.0,␣
 ↪scale=1.0, size=x_validation.shape)
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.)
```

[73]:
```
# Plotting the noised images
n = 10
plt.figure(figsize=(20, 2))
for i in range(1, n + 1):
    ax = plt.subplot(1, n, i)
    plt.imshow(x_test_noisy[i].reshape(28, 28))
    plt.gray()
    ax.get_xaxis().set_visible(False)
    ax.get_yaxis().set_visible(False)
```

```
plt.show()
```



[74]:
```
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.summary()
```

```
Model: "functional_63"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_18 (InputLayer)        [(None, 28, 28, 1)]       0
_________________________________________________________________
conv2d_27 (Conv2D)           (None, 28, 28, 32)        320
_________________________________________________________________
max_pooling2d_11 (MaxPooling (None, 14, 14, 32)        0
_________________________________________________________________
conv2d_28 (Conv2D)           (None, 14, 14, 32)        9248
_________________________________________________________________
max_pooling2d_12 (MaxPooling (None, 7, 7, 32)          0
_________________________________________________________________
conv2d_29 (Conv2D)           (None, 7, 7, 32)          9248
_________________________________________________________________
up_sampling2d_11 (UpSampling (None, 14, 14, 32)        0
_________________________________________________________________
conv2d_30 (Conv2D)           (None, 14, 14, 32)        9248
_________________________________________________________________
up_sampling2d_12 (UpSampling (None, 28, 28, 32)        0
```

```
_________________________________________________________________
conv2d_31 (Conv2D)           (None, 28, 28, 1)         289
=================================================================
Total params: 28,353
Trainable params: 28,353
Non-trainable params: 0
_________________________________________________________________
```

2.2.4 Training the noise model + plotting

[75]:
```
autoencoder.compile(optimizer='adam', loss='binary_crossentropy')

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

```
Epoch 1/30
24/24 [==============================] - 34s 1s/step - loss: 0.5513 - val_loss:
0.3879
Epoch 2/30
24/24 [==============================] - 34s 1s/step - loss: 0.3605 - val_loss:
0.3408
Epoch 3/30
24/24 [==============================] - 34s 1s/step - loss: 0.3311 - val_loss:
0.3226
Epoch 4/30
24/24 [==============================] - 34s 1s/step - loss: 0.3192 - val_loss:
0.3152
Epoch 5/30
24/24 [==============================] - 35s 1s/step - loss: 0.3132 - val_loss:
0.3108
Epoch 6/30
24/24 [==============================] - 34s 1s/step - loss: 0.3097 - val_loss:
0.3079
Epoch 7/30
24/24 [==============================] - 34s 1s/step - loss: 0.3071 - val_loss:
0.3059
Epoch 8/30
24/24 [==============================] - 34s 1s/step - loss: 0.3055 - val_loss:
0.3052
Epoch 9/30
24/24 [==============================] - 34s 1s/step - loss: 0.3038 - val_loss:
0.3029
Epoch 10/30
24/24 [==============================] - 34s 1s/step - loss: 0.3025 - val_loss:
0.3018
```

```
Epoch 11/30
24/24 [==============================] - 34s 1s/step - loss: 0.3016 - val_loss:
0.3015
Epoch 12/30
24/24 [==============================] - 35s 1s/step - loss: 0.3008 - val_loss:
0.3002
Epoch 13/30
24/24 [==============================] - 34s 1s/step - loss: 0.2999 - val_loss:
0.2992
Epoch 14/30
24/24 [==============================] - 34s 1s/step - loss: 0.2996 - val_loss:
0.2991
Epoch 15/30
24/24 [==============================] - 35s 1s/step - loss: 0.2987 - val_loss:
0.2980
Epoch 16/30
24/24 [==============================] - 34s 1s/step - loss: 0.2981 - val_loss:
0.2975
Epoch 17/30
24/24 [==============================] - 34s 1s/step - loss: 0.2976 - val_loss:
0.2975
Epoch 18/30
24/24 [==============================] - 34s 1s/step - loss: 0.2974 - val_loss:
0.2966
Epoch 19/30
24/24 [==============================] - 34s 1s/step - loss: 0.2966 - val_loss:
0.2962
Epoch 20/30
24/24 [==============================] - 34s 1s/step - loss: 0.2962 - val_loss:
0.2964
Epoch 21/30
24/24 [==============================] - 34s 1s/step - loss: 0.2964 - val_loss:
0.2958
Epoch 22/30
24/24 [==============================] - 34s 1s/step - loss: 0.2957 - val_loss:
0.2960
Epoch 23/30
24/24 [==============================] - 34s 1s/step - loss: 0.2953 - val_loss:
0.2947
Epoch 24/30
24/24 [==============================] - 34s 1s/step - loss: 0.2948 - val_loss:
0.2944
Epoch 25/30
24/24 [==============================] - 34s 1s/step - loss: 0.2945 - val_loss:
0.2941
Epoch 26/30
24/24 [==============================] - 34s 1s/step - loss: 0.2942 - val_loss:
0.2938
```

```
Epoch 27/30
24/24 [==============================] - 34s 1s/step - loss: 0.2943 - val_loss:
0.2935
Epoch 28/30
24/24 [==============================] - 34s 1s/step - loss: 0.2936 - val_loss:
0.2933
Epoch 29/30
24/24 [==============================] - 34s 1s/step - loss: 0.2935 - val_loss:
0.2931
Epoch 30/30
24/24 [==============================] - 34s 1s/step - loss: 0.2932 - val_loss:
0.2929
```

[75]:
```
<tensorflow.python.keras.callbacks.History at 0x21823c1c7b8>
```

[76]:
```
# Plotting the reconstructed images
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 denoised
    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()
```