CS156 (Introduction to AI), Fall 2022

Homework 10 submission

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References and sources

- GAN.MNIST.ipynb

Solution

Load libraries and set random number generator seed

```
import numpy as np
from tensorflow import keras
import matplotlib.pyplot as plt
from tensorflow.keras.models import Sequential
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.layers import Dense
from tensorflow.keras.layers import Conv2D
from tensorflow.keras.layers import Flatten
from tensorflow.keras.layers import Dropout
from tensorflow.keras.layers import LeakyReLU
from tensorflow.keras.utils import plot_model
from tensorflow.keras.layers import Reshape
from tensorflow.keras.layers import Conv2DTranspose
from numpy import expand_dims
from numpy import ones
from numpy import zeros
from numpy.random import rand
from numpy.random import randint
from numpy.random import randn
```

```
from numpy import vstack
```

```
np.random.seed(42)
```

Code the solution

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

(x_train, y_train), (x_test, y_test) = keras.datasets.fashion_mnist.load_data()

mnist = np.concatenate([x_train, x_test], axis=0)
mnist = expand_dims(mnist, axis=-1)

mnist = mnist.astype("float32") / 255

mnist.shape
```

```
(70000, 28, 28, 1)
```

```
def define_discriminator(in_shape=(28,28,1)):
    model = Sequential()
    model.add(Conv2D(64, (3,3), strides=(2, 2), padding='same', input_shape=in_shape))
    model.add(LeakyReLU(alpha=0.2))
    model.add(Dropout(0.4))

    model.add(Conv2D(64, (3,3), strides=(2, 2), padding='same'))
    model.add(LeakyReLU(alpha=0.2))
    model.add(Dropout(0.4))

    model.add(Conv2D(64, (5,5), strides=(1, 1), padding='same'))
    model.add(LeakyReLU(alpha=0.2))
    model.add(Dropout(0.4))

    model.add(Flatten())
    model.add(Dense(1, activation='sigmoid'))

    opt = Adam(lr=0.0002, beta_1=0.5)
    model.compile(loss='binary_crossentropy', optimizer=opt, metrics=['accuracy'])
    return model


discriminator = define_discriminator()
discriminator.summary()
```

```
Model: "sequential_3"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 conv2d_4 (Conv2D)           (None, 14, 14, 64)        640
```

```
 leaky_re_lu_7 (LeakyReLU)   (None, 14, 14, 64)        0

 dropout_3 (Dropout)         (None, 14, 14, 64)        0

 conv2d_5 (Conv2D)           (None, 7, 7, 64)          36928

 leaky_re_lu_8 (LeakyReLU)   (None, 7, 7, 64)          0

 dropout_4 (Dropout)         (None, 7, 7, 64)          0

 conv2d_6 (Conv2D)           (None, 7, 7, 64)          102464

 leaky_re_lu_9 (LeakyReLU)   (None, 7, 7, 64)          0

 dropout_5 (Dropout)         (None, 7, 7, 64)          0

 flatten_1 (Flatten)         (None, 3136)              0

 dense_2 (Dense)             (None, 1)                 3137

=================================================================
Total params: 143,169
Trainable params: 143,169
Non-trainable params: 0
_________________________________________________________________
```

```
def define_generator(latent_dim):
    model = Sequential()

    n_nodes = 128 * 7 * 7
    model.add(Dense(n_nodes, input_dim=latent_dim))
    model.add(LeakyReLU(alpha=0.2))
    model.add(Reshape((7, 7, 128)))


    model.add(Conv2DTranspose(128, (4,4), strides=(2,2), padding='same'))
    model.add(LeakyReLU(alpha=0.2))

    model.add(Conv2DTranspose(128, (1,1), strides=(1,1), padding='same'))
    model.add(LeakyReLU(alpha=0.2))

    model.add(Conv2DTranspose(128, (4,4), strides=(2,2), padding='same'))
    model.add(LeakyReLU(alpha=0.2))
    model.add(Conv2D(1, (7,7), activation='sigmoid', padding='same'))
    return model

latent_dim = 100

generator = define_generator(latent_dim)
generator.summary()
```

```
Model: "sequential_4"
```

```
 ________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 dense_3 (Dense)             (None, 6272)              633472

 leaky_re_lu_10 (LeakyReLU)  (None, 6272)              0

 reshape_1 (Reshape)         (None, 7, 7, 128)         0

 conv2d_transpose_3 (Conv2DT  (None, 14, 14, 128)      262272
 ranspose)

 leaky_re_lu_11 (LeakyReLU)  (None, 14, 14, 128)       0

 conv2d_transpose_4 (Conv2DT  (None, 14, 14, 128)      16512
 ranspose)

 leaky_re_lu_12 (LeakyReLU)  (None, 14, 14, 128)       0

 conv2d_transpose_5 (Conv2DT  (None, 28, 28, 128)      262272
 ranspose)

 leaky_re_lu_13 (LeakyReLU)  (None, 28, 28, 128)       0

 conv2d_7 (Conv2D)           (None, 28, 28, 1)         6273

=================================================================
Total params: 1,180,801
Trainable params: 1,180,801
Non-trainable params: 0
_________________________________________________________________
```

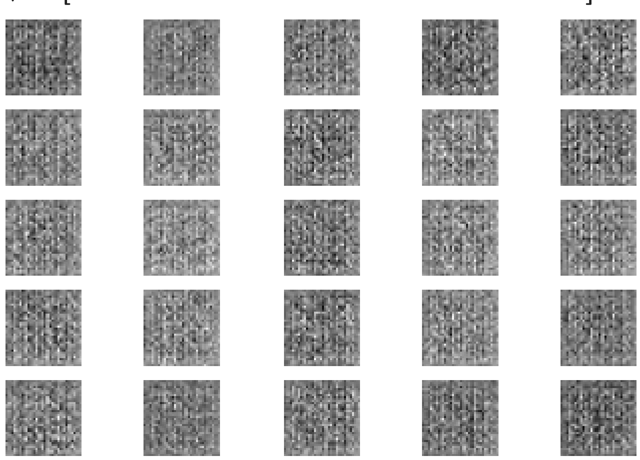
```
def define_gan(g_model, d_model):

    d_model.trainable = False

    model = Sequential()

    model.add(g_model)

    model.add(d_model)

    opt = Adam(lr=0.0002, beta_1=0.5)
    model.compile(loss='binary_crossentropy', optimizer=opt)
    return model

gan_model = define_gan(generator, discriminator)
gan_model.summary()
```

```
Model: "sequential_5"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 sequential_4 (Sequential)   (None, 28, 28, 1)         1180801
```

```
 sequential_3 (Sequential)   (None, 1)                 143169

=================================================================
Total params: 1,323,970
Trainable params: 1,180,801
Non-trainable params: 143,169
_________________________________________________________________
```

```
def generate_latent_points(latent_dim, n_samples):
    x_input = randn(latent_dim * n_samples)
    x_input = x_input.reshape(n_samples, latent_dim)
    return x_input

def generate_fake_generator_samples(g_model, latent_dim, n_samples):
    x_input = generate_latent_points(latent_dim, n_samples)
    X = g_model.predict(x_input)
    y = zeros((n_samples, 1))
    return X, y

n_samples = 25
X, _ = generate_fake_generator_samples(generator, latent_dim, n_samples)
for i in range(n_samples):

    plt.subplot(5, 5, 1 + i)

    plt.axis('off')

    plt.imshow(X[i, :, :, 0], cmap='gray_r')

plt.show()
```

```
1/1 [==============================] - 0s 274ms/step
```



```
def generate_real_samples(dataset, n_samples):

    ix = randint(0, dataset.shape[0], n_samples)
```

```
    X = dataset[ix]
    y = ones((n_samples, 1))
    return X, y

def generate_fake_samples(g_model, latent_dim, n_samples):
    x_input = generate_latent_points(latent_dim, n_samples)
    X = g_model.predict(x_input)
    y = zeros((n_samples, 1))
    return X, y

def generate_latent_points(latent_dim, n_samples):
    x_input = randn(latent_dim * n_samples)
    x_input = x_input.reshape(n_samples, latent_dim)
    return x_input
def summarize_performance(epoch, g_model, d_model, dataset, latent_dim, n_samples=100)

    X_real, y_real = generate_real_samples(dataset, n_samples)

    _, acc_real = d_model.evaluate(X_real, y_real, verbose=0)

    x_fake, y_fake = generate_fake_samples(g_model, latent_dim, n_samples)

    _, acc_fake = d_model.evaluate(x_fake, y_fake, verbose=0)

    print('>Accuracy real: %.0f%%, fake: %.0f%%' % (acc_real*100, acc_fake*100))

def train(g_model, d_model, gan_model, dataset, latent_dim, n_epochs=10, n_batch=256):
    bat_per_epo = int(dataset.shape[0] / n_batch)
    half_batch = int(n_batch / 2)

    for i in range(n_epochs):

        for j in range(bat_per_epo):

            X_real, y_real = generate_real_samples(dataset, half_batch)

            X_fake, y_fake = generate_fake_samples(g_model, latent_dim, half_batch)

            X, y = vstack((X_real, X_fake)), vstack((y_real, y_fake))

            d_loss, _ = d_model.train_on_batch(X, y)

            X_gan = generate_latent_points(latent_dim, n_batch)

            y_gan = ones((n_batch, 1))

            g_loss = gan_model.train_on_batch(X_gan, y_gan)

            print('>%d, %d/%d, d_loss=%.3f, g_loss=%.3f' % (i+1, j+1, bat_per_epo, d_l
```

```
        summarize_performance(i, g_model, d_model, dataset, latent_dim)

        return g_model


latent_dim = 100

trained_generator = train(generator, discriminator, gan_model, mnist, latent_dim, 10)
```

```
4/4 [==============================] - 1s 262ms/step
>10, 246/273, d_loss=0.683, g_loss=0.693
4/4 [==============================] - 1s 216ms/step
>10, 247/273, d_loss=0.692, g_loss=0.719
4/4 [==============================] - 1s 227ms/step
>10, 248/273, d_loss=0.671, g_loss=0.773
4/4 [==============================] - 1s 217ms/step
>10, 249/273, d_loss=0.675, g_loss=0.777
4/4 [==============================] - 1s 213ms/step
>10, 250/273, d_loss=0.688, g_loss=0.778
4/4 [==============================] - 1s 240ms/step
>10, 251/273, d_loss=0.669, g_loss=0.722
4/4 [==============================] - 1s 219ms/step
>10, 252/273, d_loss=0.670, g_loss=0.704
4/4 [==============================] - 1s 208ms/step
>10, 253/273, d_loss=0.668, g_loss=0.731
4/4 [==============================] - 1s 214ms/step
>10, 254/273, d_loss=0.674, g_loss=0.754
4/4 [==============================] - 1s 213ms/step
>10, 255/273, d_loss=0.668, g_loss=0.723
4/4 [==============================] - 1s 215ms/step
>10, 256/273, d_loss=0.672, g_loss=0.697
4/4 [==============================] - 1s 210ms/step
>10, 257/273, d_loss=0.675, g_loss=0.673
4/4 [==============================] - 1s 221ms/step
>10, 258/273, d_loss=0.663, g_loss=0.675
4/4 [==============================] - 1s 221ms/step
>10, 259/273, d_loss=0.701, g_loss=0.764
4/4 [==============================] - 1s 216ms/step
>10, 260/273, d_loss=0.688, g_loss=0.876
4/4 [==============================] - 1s 218ms/step
>10, 261/273, d_loss=0.680, g_loss=0.909
4/4 [==============================] - 1s 214ms/step
>10, 262/273, d_loss=0.689, g_loss=0.777
4/4 [==============================] - 1s 217ms/step
>10, 263/273, d_loss=0.681, g_loss=0.688
4/4 [==============================] - 1s 211ms/step
>10, 264/273, d_loss=0.669, g_loss=0.624
4/4 [==============================] - 1s 218ms/step
>10, 265/273, d_loss=0.678, g_loss=0.635
4/4 [==============================] - 1s 218ms/step
>10, 266/273, d_loss=0.654, g_loss=0.669
4/4 [==============================] - 1s 215ms/step
>10, 267/273, d_loss=0.675, g_loss=0.737
4/4 [==============================] - 1s 220ms/step
>10, 268/273, d_loss=0.684, g_loss=0.843
4/4 [==============================] - 1s 220ms/step
```

```
>10, 269/273, d_loss=0.671, g_loss=0.885
4/4 [==============================] - 1s 227ms/step
>10, 270/273, d_loss=0.678, g_loss=0.872
4/4 [==============================] - 1s 220ms/step
>10, 271/273, d_loss=0.651, g_loss=0.767
4/4 [==============================] - 1s 217ms/step
>10, 272/273, d_loss=0.658, g_loss=0.769
4/4 [==============================] - 1s 219ms/step
>10, 273/273, d_loss=0.676, g_loss=0.720
4/4 [==============================] - 1s 161ms/step
>Accuracy real: 76%, fake: 39%
```

```
def generate_latent_points(latent_dim, n_samples):

    x_input = randn(latent_dim * n_samples)

    x_input = x_input.reshape(n_samples, latent_dim)
    return x_input

def display_plot(examples, n):
    for i in range(n * n):
        plt.subplot(n, n, 1 + i)
        plt.axis('off')
        plt.imshow(examples[i, :, :, 0], cmap='gray_r')
    plt.show()

latent_points = generate_latent_points(100, 25)

X = trained_generator.predict(latent_points)

display_plot(X, 5)
```

```
1/1 [==============================] - 0s 180ms/step
```

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