Kaggle GAN Competition: Dog Images

Challenge Problem:

In this task, we aim to generate realistic data samples from a complex and high-dimensional true data distribution, , which is often inaccessible. To achieve this, we will employ a Generative Adversarial Network (GAN), consisting of two neural networks: a Generator G and a Discriminator D. The Generator creates synthetic data samples by transforming random noise into data resembling the true distribution, while the Discriminator distinguishes between real and fake samples. These networks are trained simultaneously in a game-theoretic manner, where the Generator aims to fool the Discriminator, and the Discriminator works to correctly identify real versus fake data. This adversarial process improves the performance of both networks, gradually allowing the Generator to produce more realistic data.

Source # https://www.kaggle.com/competitions/gan-getting-started/overview

```
import warnings
import os
import time
from glob import glob
import datetime
import seaborn as sns
import numpy as np, pandas as pd, os
import keras
import matplotlib.pyplot as plt, zipfile
from PIL import Image

import zipfile
from keras.layers import Input, Dense, Reshape, Flatten, Dropout,Concatenate
from tensorflow.keras.backend import random_normal, ones_like, zeros_like, mean
from keras.layers import Conv2D, UpSampling2D
from keras.layers import BatchNormalization, Activation, ZeroPadding2D
from keras.models import Sequential, Model
from keras.optimizers import Adam
from keras.layers import concatenate
from keras.initializers import TruncatedNormal
from keras.callbacks import LearningRateScheduler, EarlyStopping, History
from PIL import Image
import warnings
import xml.etree.ElementTree as ET
import os
print(os.listdir("/kaggle/input/generative-dog-images"))
```

```
['Annotation.zip', 'all-dogs.zip']
```

```
with zipfile.ZipFile("../input/generative-dog-images/all-dogs.zip","r") as z:
    z.extractall("/kaggle/working/")

dog_dir = "/kaggle/working/all-dogs/"
filenames = os.listdir(dog_dir)

print('Total images:', len(filenames))

with zipfile.ZipFile("../input/generative-dog-images/Annotation.zip","r") as z:
    z.extractall("/kaggle/working/")

dog_dir_Annotation = "/kaggle/working/Annotation/"
filenames_Annotation = os.listdir(dog_dir_Annotation)

print('Total images:', len(filenames_Annotation))
```

```
Total images: 20579
Total images: 120
```

```
ComputeLB = False
DogsOnly = False


ROOT = '/kaggle/working/'
if not ComputeLB: ROOT = '/kaggle/working/'
```

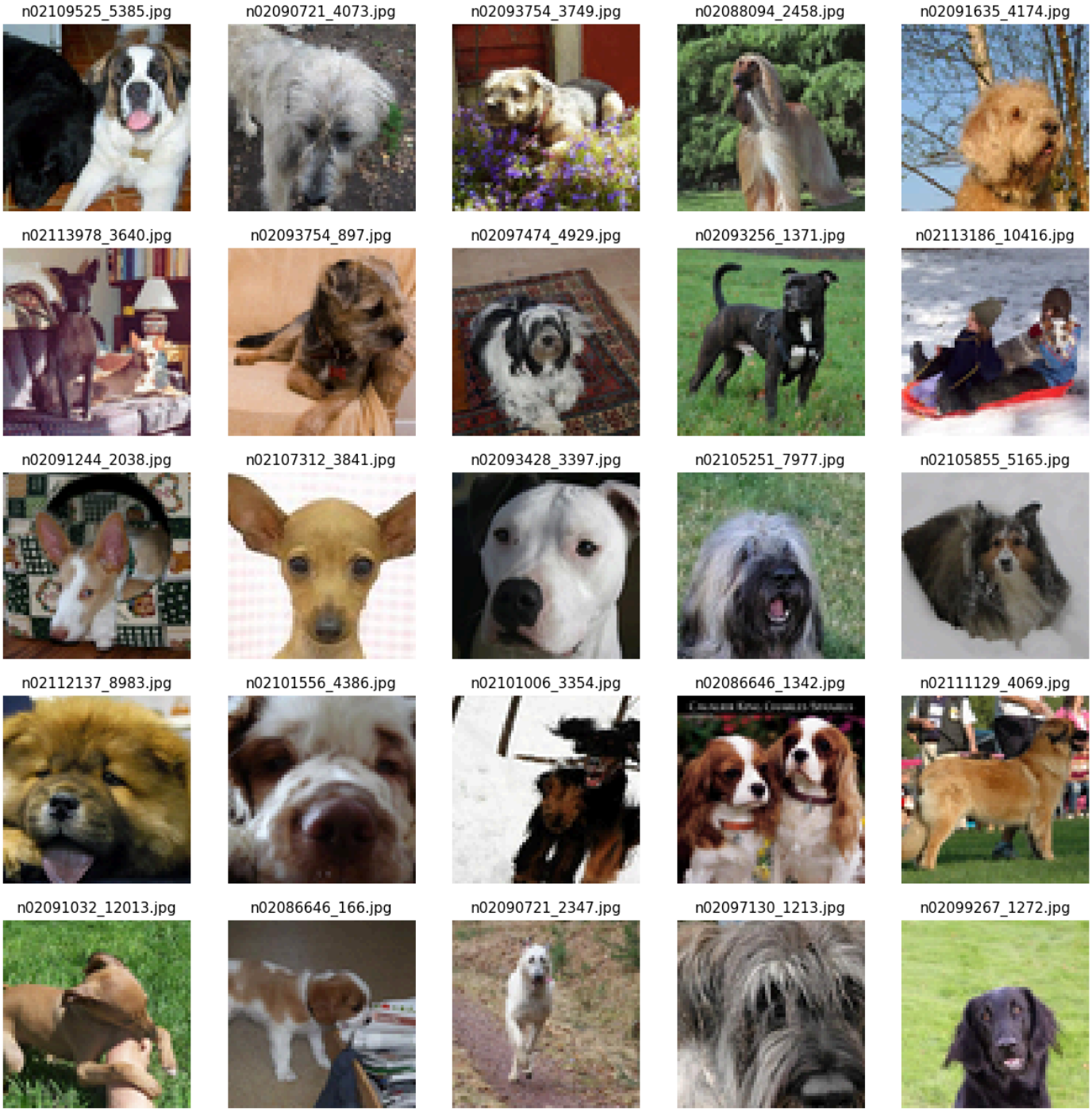
```
IMAGES = os.listdir(ROOT + 'all-dogs/')
breeds = os.listdir(ROOT + 'Annotation/')

idxIn = 0; namesIn = []
imagesIn = np.zeros((25000,64,64,3))


# CROP WITH BOUNDING BOXES TO GET DOGS ONLY
# https://www.kaggle.com/paulorzp/show-annotations-and-breeds
if DogsOnly:
    for breed in breeds:
        for dog in os.listdir(ROOT+'Annotation/'+breed):
            try: img = Image.open(ROOT+'all-dogs/'+dog+'.jpg')
            except: continue
            tree = ET.parse(ROOT+'Annotation/'+breed+'/'+dog)
            root = tree.getroot()
            objects = root.findall('object')
            for o in objects:
                bndbox = o.find('bndbox')
                xmin = int(bndbox.find('xmin').text)
                ymin = int(bndbox.find('ymin').text)
                xmax = int(bndbox.find('xmax').text)
                ymax = int(bndbox.find('ymax').text)
                w = np.min((xmax - xmin, ymax - ymin))
                img2 = img.crop((xmin, ymin, xmin+w, ymin+w))
                img2 = img2.resize((64,64), Image.ANTIALIAS)
                imagesIn[idxIn,:,:,:] = np.asarray(img2)
                #if idxIn%1000==0: print(idxIn)
                namesIn.append(breed)
                idxIn += 1
    idx = np.arange(idxIn)
    np.random.shuffle(idx)
    imagesIn = imagesIn[idx,:,:,:]
    namesIn = np.array(namesIn)[idx]

# RANDOMLY CROP FULL IMAGES
else:
    IMAGES = np.sort(IMAGES)
    np.random.seed(810)
    x = np.random.choice(np.arange(20579),10000)
    np.random.seed(None)
    for k in range(len(x)):
        img = Image.open(ROOT + 'all-dogs/' + IMAGES[x[k]])
        w = img.size[0]; h = img.size[1];
        if (k%2==0)|(k%3==0):
            w2 = 100; h2 = int(h/(w/100))
            a = 18; b = 0
        else:
            a=0; b=0
            if w<h:
                w2 = 64; h2 = int((64/w)*h)
                b = (h2-64)//2
            else:
                h2 = 64; w2 = int((64/h)*w)
                a = (w2-64)//2
        img = img.resize((w2,h2), Image.Resampling.LANCZOS)
        img = img.crop((0+a, 0+b, 64+a, 64+b))
        imagesIn[idxIn,:,:,:] = np.asarray(img)
        namesIn.append(IMAGES[x[k]])
        #if idxIn%1000==0: print(idxIn)
        idxIn += 1

# DISPLAY CROPPED IMAGES
x = np.random.randint(0,idxIn,25)
for k in range(5):
    plt.figure(figsize=(15,3))
    for j in range(5):
        plt.subplot(1,5,j+1)
        img = Image.fromarray( imagesIn[x[k*5+j],:,:,:].astype('uint8') )
        plt.axis('off')
        if not DogsOnly: plt.title(namesIn[x[k*5+j]],fontsize=11)
        else: plt.title(namesIn[x[k*5+j]].split('-')[1],fontsize=11)
        plt.imshow(img)
    plt.show()
```




```
IMG_SIZE = Input((12288,))
IMG_SIZE_2 = Input((10000,))
NOISE_SIZE = 10000
#BATCH_SIZE = 256 # orig gives ~7.24
#BATCH_SIZE = 512 # gives ~7.25
BATCH_SIZE = 128 # gives 7.22594
#BATCH_SIZE = 128 # gives ~7.222
#BATCH_SIZE = 64
```

Build Discriminator

```
def discriminatorFunction():

    input_layer = Dense(12288, activation='sigmoid')(IMG_SIZE_2)
    input_layer = Reshape((2,12288,1))(concatenate([IMG_SIZE,input_layer]))
    discriminator = Conv2D(filters = 1, kernel_size=[2,1],use_bias=False, name = 'layer_1')(input_layer)
    out = Flatten()(discriminator)
    return out


print("Discriminator")
model = discriminatorFunction()
model_discriminator = Model([IMG_SIZE,IMG_SIZE_2], model)
model_discriminator.get_layer('layer_1').trainable = False
model_discriminator.get_layer('layer_1').set_weights([np.array([[[[-1.0 ]]],[[[1.0]]]])])
model_discriminator.summary()
model_discriminator.compile(optimizer='adam', loss='binary_crossentropy')
```

```
Discriminator
I0000 00:00:1745788134.278856      31 gpu_device.cc:2022] Created device /job:localhost/replica:0/task:0/device:GPU:0 with 13942 MB memc
I0000 00:00:1745788134.279680      31 gpu_device.cc:2022] Created device /job:localhost/replica:0/task:0/device:GPU:1 with 13942 MB memc
Model: "functional"
```

Layer (type)	Output Shape	Param #	Connected to
input_layer_3 (InputLayer)	(None, 10000)	0	-
input_layer_2 (InputLayer)	(None, 12288)	0	-
dense (Dense)	(None, 12288)	122,892,288	input_layer_3[0][0]
concatenate (Concatenate)	(None, 24576)	0	input_layer_2[0][0], dense[0][0]
reshape (Reshape)	(None, 2, 12288, 1)	0	concatenate[0][0]
layer_1 (Conv2D)	(None, 1, 12288, 1)	2	reshape[0][0]
flatten (Flatten)	(None, 12288)	0	layer_1[0][0]

```
Total params: 122,892,290 (468.80 MB)
Trainable params: 122,892,288 (468.80 MB)
```

Build Generator

```
def GeneratorFunction(noise_shape=(NOISE_SIZE,)):
    input_layer = Input(noise_shape)
    generated = Dense(12288, activation='linear')(input_layer)

# COMPILE
    model = Model(inputs=input_layer,outputs = [generated,Reshape((10000,))(input_layer)])
    model.summary()

    return model

print("Generator")
model_generator = GeneratorFunction(noise_shape=(NOISE_SIZE,))
```

Generator
Model: "functional_1"

Layer (type)	Output Shape	Param #	Connected to
input_layer_6 (InputLayer)	(None, 10000)	0	-
dense_1 (Dense)	(None, 12288)	122,892,288	input_layer_6[0][0]
reshape_1 (Reshape)	(None, 10000)	0	input_layer_6[0][0]

Total params: 122,892,288 (468.80 MB)
Trainable params: 122,892,288 (468.80 MB)

Training the Discriminator

```
# TRAINING DATA
train_y = (imagesIn[:10000,:,:,:]/255.).reshape((-1,12288))
train_X = np.zeros((10000,10000))
for i in range(10000): train_X[i,i] = 1
zeros = np.zeros((10000,12288))

# ---------------------
#  Train Discriminator
# ---------------------

lr = 0.5
for k in range(5):
    LR_Scheduler = LearningRateScheduler(lambda x: lr)
    h = model_discriminator.fit([zeros,train_X], train_y, epochs = 100,batch_size = BATCH_SIZE, callbacks=[LR_Scheduler], verbose=0)
    print('Epoch',(k+1)*10,'/50 - loss =',h.history['loss'][-1] )
    if h.history['loss'][-1]<0.533: lr = 0.1
```

```
WARNING: All log messages before absl::InitializeLog() is called are written to STDERR
I0000 00:00:1745788173.749432      98 service.cc:148] XLA service 0x7f85d80090b0 initialized for platform CUDA (this does not guarantee
I0000 00:00:1745788173.751311      98 service.cc:156]   StreamExecutor device (0): Tesla T4, Compute Capability 7.5
I0000 00:00:1745788173.751346      98 service.cc:156]   StreamExecutor device (1): Tesla T4, Compute Capability 7.5
I0000 00:00:1745788174.044371      98 cuda_dnn.cc:529] Loaded cuDNN version 90300
I0000 00:00:1745788176.815428      98 device_compiler.h:188] Compiled cluster using XLA!  This line is logged at most once for the lifet
Epoch 10 /50 - loss = 0.5325140357017517
Epoch 20 /50 - loss = 0.5324963927268982
Epoch 30 /50 - loss = 0.5324907302856445
Epoch 40 /50 - loss = 0.5324869155883789
Epoch 50 /50 - loss = 0.5324838757514954
```

```
del train_X, train_y, imagesIn
```

Building GAN

We will purposely give our Generator a bottleneck in its memory. Using poor memory forces the Generator to learn a generalization of images and not memorize the images exactly.

```
# BUILD GENERATOR NETWORK
BadMemory = True

if BadMemory:
    seed = Input((10000,))
    x = Dense(2048, activation='elu')(seed)
    x = Reshape((8,8,32))(x)
    x = Conv2D(128, (3, 3), activation='elu', padding='same')(x)
    x = UpSampling2D((2, 2))(x)
    x = Conv2D(64, (3, 3), activation='elu', padding='same')(x)
    x = UpSampling2D((2, 2))(x)
    x = Conv2D(32, (3, 3), activation='elu', padding='same')(x)
    x = UpSampling2D((2, 2))(x)
    x = Conv2D(3, (3, 3), activation='linear', padding='same')(x)
    generated = Flatten()(x)
else:
    seed = Input((10000,))
```

```
    generated = Dense(12288, activation='linear')(seed)

# COMPILE
generator = Model(seed, [generated,Reshape((10000,))(seed)])

# DISPLAY ARCHITECTURE
generator.summary()
```

Model: "functional_11"

Layer (type)	Output Shape	Param #	Connected to
input_layer_27 (InputLayer)	(None, 10000)	0	-
dense_2 (Dense)	(None, 2048)	20,482,048	input_layer_27[0][0]
reshape_2 (Reshape)	(None, 8, 8, 32)	0	dense_2[0][0]
conv2d (Conv2D)	(None, 8, 8, 128)	36,992	reshape_2[0][0]
up_sampling2d (UpSampling2D)	(None, 16, 16, 128)	0	conv2d[0][0]
conv2d_1 (Conv2D)	(None, 16, 16, 64)	73,792	up_sampling2d[0][0]
up_sampling2d_1 (UpSampling2D)	(None, 32, 32, 64)	0	conv2d_1[0][0]
conv2d_2 (Conv2D)	(None, 32, 32, 32)	18,464	up_sampling2d_1[0][0]
up_sampling2d_2 (UpSampling2D)	(None, 64, 64, 32)	0	conv2d_2[0][0]
conv2d_3 (Conv2D)	(None, 64, 64, 3)	867	up_sampling2d_2[0][0]
flatten_1 (Flatten)	(None, 12288)	0	conv2d_3[0][0]
reshape_3 (Reshape)	(None, 10000)	0	input_layer_27[0][0]

```
# BUILD GENERATIVE ADVERSARIAL NETWORK
model_discriminator.trainable = False

gan_input = Input(shape=(10000,))
x = generator(gan_input)
gan_output = model_discriminator(x)

gan = Model(gan_input, gan_output)

# Correct setting of conv2d weights
conv_layer = gan.get_layer('functional_11').get_layer('conv2d_1')
weights = conv_layer.get_weights()

# Set weights properly
new_kernel = np.zeros_like(weights[0])
new_bias = np.zeros_like(weights[1])
conv_layer.set_weights([new_kernel, new_bias])

# COMPILE GAN
gan.compile(optimizer=Adam(learning_rate=5.0), loss='mean_squared_error')

# DISPLAY ARCHITECTURE
gan.summary()
```

Model: "functional_22"

Layer (type)	Output Shape	Param #	Connected to
input_layer_38 (InputLayer)	(None, 10000)	0	-
functional_11 (Functional)	[(None, 12288), (None, 10000)]	20,612,163	input_layer_38[0][0]
functional (Functional)	(None, 12288)	122,892,290	functional_11[10][0], functional_11[10][1]

Total params: 143,504,453 (547.43 MB)

Training GAN

```
train = np.zeros((10000,10000))
for i in range(10000): train[i,i] = 1
zeros = np.zeros((10000,12288))*500

Steps_per_epoch = 50
print("Training begins... Total steps per epoch: {}".format(Steps_per_epoch ))
```

```
Training begins... Total steps per epoch: 50
```

```
# TRAIN NETWORKS
ep = 1; it = 9
if BadMemory: lr = 0.005
else: lr = 5.

for k in range(it):

    # BEGIN DISCRIMINATOR COACHES GENERATOR
    annealer = LearningRateScheduler(lambda x: lr)
    h = gan.fit(train, zeros, epochs = 10, batch_size=128, callbacks=[annealer], verbose=0)

    # DISPLAY GENERATOR LEARNING PROGRESS
    print('Epoch',(k+1),'/'+str(it)+' - loss =',h.history['loss'][-1] )
    plt.figure(figsize=(15,3))
    for j in range(5):
        xx = np.zeros((10000))
        xx[np.random.randint(10000)] = 1
        plt.subplot(1,5,j+1)
        img = generator.predict(xx.reshape((-1, 10000)))[0]

        # Ensure the image is reshaped to (64, 64, 3)
        img = img.reshape((64, 64, 3))

        # Replace NaNs or Infs with 0
        img = np.nan_to_num(img, nan=0.0, posinf=255, neginf=0)

        # Clip image values to be within the valid range for uint8 (0-255)
        img = np.clip(img, 0, 255).astype('uint8')
        img_pil = Image.fromarray(img)
        plt.axis('off')
        plt.imshow(img)
    plt.show()

    # ADJUST LEARNING RATES
    if BadMemory:
        ep *= 2
        if ep>=32: lr = 0.001
        if ep>256: ep = 256
    else:
        if h.history['loss'][-1] < 25: lr = 1.
        if h.history['loss'][-1] < 1.5: lr = 0.5
```

```
Epoch 1 /9 - loss = 0.0
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 21ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
```

```
Epoch 2 /9 - loss = 0.0
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 20ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 19ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 18ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 16ms/step
```

```
Epoch 3 /9 - loss = 0.0
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 21ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 16ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 17ms/step
1/1 ━━━━━━━━━━━━━━━━━━━━ 0s 16ms/step
```

```
---------------------------------------------------------------------------
KeyboardInterrupt                         Traceback (most recent call last)
/tmp/ipykernel_31/2868487983.py in <cell line: 0>()
      8     # BEGIN DISCRIMINATOR COACHES GENERATOR
      9     annealer = LearningRateScheduler(lambda x: lr)
```