

# Generating Monet-Style Images Using GANs

## Description of the Problem

Generative Adversarial Networks (GANs) are a class of neural networks used for generating new data that mimics a given dataset. In this project, we aim to build a GAN that generates images in the style of the famous artist Claude Monet. The goal is to generate between 7,000 to 10,000 Monet-style images.

The GAN consists of two neural networks:

- Generator: Creates new images that resemble the Monet-style paintings.
- Discriminator: Distinguishes between real Monet paintings and images generated by the generator.

These two networks are trained simultaneously in a game-theoretic framework where the generator tries to fool the discriminator, and the discriminator aims to correctly classify real and generated images.

## Importing Libraries

```
In [1]: import numpy as np
import pandas as pd
import matplotlib.pyplot as plt
import os
from glob import glob
import tensorflow as tf
from tensorflow.keras.layers import *
from tensorflow.keras.models import Model
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.preprocessing.image import load_img, img_to_array
```

```
In [ ]: from tensorflow.python.client import device_lib

def get_available_devices():
    local_device_protos = device_lib.list_local_devices()
    return [x.name for x in local_device_protos]

print(get_available_devices())
```

```
['/device:CPU:0', '/device:GPU:0']
```

## Loading and Preprocessing the Data

```
In [5]: # Set the path to the dataset
monet_path = 'monet_jpg/'
```

```

photo_path = 'photo_jpg/'

# Get the list of image file paths
monet_images = glob(os.path.join(monet_path, '*.jpg'))
photo_images = glob(os.path.join(photo_path, '*.jpg'))

print(f'Total Monet images: {len(monet_images)}')
print(f'Total Photo images: {len(photo_images)}')

# Function to Load and preprocess images
def load_and_preprocess_image(image_path, img_size=(256, 256)):
    img = load_img(image_path, target_size=img_size)
    img = img_to_array(img)
    img = (img - 127.5) / 127.5 # Normalize to [-1, 1]
    return img

# Load images into numpy arrays
monet_data = np.array([load_and_preprocess_image(img) for img in monet_images])
photo_data = np.array([load_and_preprocess_image(img) for img in photo_images])

print(f'Monet data shape: {monet_data.shape}')
print(f'Photo data shape: {photo_data.shape}')

```

Total Monet images: 300

Total Photo images: 7038

Monet data shape: (300, 256, 256, 3)

Photo data shape: (7038, 256, 256, 3)

## Exploratory Data Analysis (EDA)

Let's visualize some samples from both datasets.

```

In [6]: # Function to display images
def display_samples(data, title, n=5):
    plt.figure(figsize=(20, 4))
    plt.suptitle(title, fontsize=20)
    for i in range(n):
        plt.subplot(1, n, i+1)
        plt.imshow((data[i] * 0.5 + 0.5))
        plt.axis('off')
    plt.show()

display_samples(monet_data, 'Monet Paintings')
display_samples(photo_data, 'Photos')

```

Monet Paintings



Photos



## Observations:

- The Monet paintings have distinctive brush strokes and color palettes.
- The photos are realistic images that we aim to translate into Monet's style.

## Building the GAN Model

We will use a CycleGAN architecture, which is effective for image-to-image translation tasks.

## Generator Model

```
In [7]: def build_generator():
        inputs = Input(shape=(256, 256, 3))

        # Downsampling Layers
        x = Conv2D(64, kernel_size=4, strides=2, padding='same')(inputs)
        x = LeakyReLU(alpha=0.2)(x)
        # Add more Layers as needed...

        # Upsampling Layers
        x = Conv2DTranspose(64, kernel_size=4, strides=2, padding='same')(x)
        x = Activation('tanh')(x)
        # Add more Layers as needed...

        outputs = Conv2D(3, kernel_size=7, padding='same', activation='tanh')(x)
        model = Model(inputs, outputs, name='Generator')
        return model

generator = build_generator()
generator.summary()
```

Model: "Generator"

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	[(None, 256, 256, 3)]	0
conv2d (Conv2D)	(None, 128, 128, 64)	3136
leaky_re_lu (LeakyReLU)	(None, 128, 128, 64)	0
conv2d_transpose (Conv2DTranspose)	(None, 256, 256, 64)	65600
activation (Activation)	(None, 256, 256, 64)	0
conv2d_1 (Conv2D)	(None, 256, 256, 3)	9411

=====  
Total params: 78,147  
Trainable params: 78,147

Layer (type)	Output Shape	Param #
input_1 (InputLayer)	[(None, 256, 256, 3)]	0
conv2d (Conv2D)	(None, 128, 128, 64)	3136
leaky_re_lu (LeakyReLU)	(None, 128, 128, 64)	0
conv2d_transpose (Conv2DTranspose)	(None, 256, 256, 64)	65600
activation (Activation)	(None, 256, 256, 64)	0
conv2d_1 (Conv2D)	(None, 256, 256, 3)	9411

=====  
Total params: 78,147  
Trainable params: 78,147  
Non-trainable params: 0

## Discriminator Model

```
In [8]: def build_discriminator():
        inputs = Input(shape=(256, 256, 3))

        x = Conv2D(64, kernel_size=4, strides=2, padding='same')(inputs)
        x = LeakyReLU(alpha=0.2)(x)
        # Add more Layers as needed...

        outputs = Conv2D(1, kernel_size=4, padding='same')(x)
        model = Model(inputs, outputs, name='Discriminator')
        return model
```

```
discriminator = build_discriminator()
discriminator.summary()
```

Model: "Discriminator"

Layer (type)	Output Shape	Param #
=====		
input_2 (InputLayer)	[(None, 256, 256, 3)]	0
conv2d_2 (Conv2D)	(None, 128, 128, 64)	3136
leaky_re_lu_1 (LeakyReLU)	(None, 128, 128, 64)	0
conv2d_3 (Conv2D)	(None, 128, 128, 1)	1025

```
=====
Total params: 4,161
Trainable params: 4,161
Non-trainable params: 0
```

Layer (type)	Output Shape	Param #
=====		
input_2 (InputLayer)	[(None, 256, 256, 3)]	0
conv2d_2 (Conv2D)	(None, 128, 128, 64)	3136
leaky_re_lu_1 (LeakyReLU)	(None, 128, 128, 64)	0
conv2d_3 (Conv2D)	(None, 128, 128, 1)	1025

```
=====
Total params: 4,161
Trainable params: 4,161
Non-trainable params: 0
```

## Compiling the Models

```
In [9]: # Optimizers
opt = Adam(learning_rate=0.0002, beta_1=0.5)

# Compile Discriminator
discriminator.compile(loss='mse', optimizer=opt, loss_weights=[0.5])

# Build and compile the combined model
def build_gan(generator, discriminator):
    discriminator.trainable = False
    gan_input = Input(shape=(256, 256, 3))
    generated_image = generator(gan_input)
    gan_output = discriminator(generated_image)
    gan = Model(gan_input, gan_output)
    gan.compile(loss='mse', optimizer=opt)
    return gan
```

```
gan = build_gan(generator, discriminator)
gan.summary()
```

Model: "model"

Layer (type)	Output Shape	Param #
=====		
input_3 (InputLayer)	[(None, 256, 256, 3)]	0
Generator (Functional)	(None, 256, 256, 3)	78147
Discriminator (Functional)	(None, 128, 128, 1)	4161
=====		
Total params: 82,308		
Trainable params: 78,147		
Non-trainable params: 4,161		

Layer (type)	Output Shape	Param #
=====		
input_3 (InputLayer)	[(None, 256, 256, 3)]	0
Generator (Functional)	(None, 256, 256, 3)	78147
Discriminator (Functional)	(None, 128, 128, 1)	4161
=====		
Total params: 82,308		
Trainable params: 78,147		
Non-trainable params: 4,161		

## Training the GAN

```
In [12]: import datetime

def train_gan(generator, discriminator, epochs, batch_size):
    # Ensure models are trainable
    generator.trainable = True
    discriminator.trainable = True

    # Create optimizers
    generator_optimizer = tf.keras.optimizers.Adam(learning_rate=0.0002, beta_1=0.5)
    discriminator_optimizer = tf.keras.optimizers.Adam(learning_rate=0.0002, beta_1=0.5)

    # Loss function
    cross_entropy = tf.keras.losses.BinaryCrossentropy(from_logits=False)

    def train_step(real_images, images):
        with tf.GradientTape() as gen_tape, tf.GradientTape() as disc_tape:
            # Generate fake images
            generated_images = generator(images, training=True)

            # Discriminator output
```

```

real_output = discriminator(real_images, training=True)
fake_output = discriminator(generated_images, training=True)

# Calculate losses
d_loss_real = cross_entropy(tf.ones_like(real_output), real_output)
d_loss_fake = cross_entropy(tf.zeros_like(fake_output), fake_output)
d_loss = (d_loss_real + d_loss_fake) * 0.5

g_loss = cross_entropy(tf.ones_like(fake_output), fake_output)

# Calculate gradients
gradients_of_generator = gen_tape.gradient(g_loss, generator.trainable_variables)
gradients_of_discriminator = disc_tape.gradient(d_loss, discriminator.trainable_variables)

# Check for None gradients
if any(grad is None for grad in gradients_of_generator):
    print("Warning: Some generator gradients are None")
if any(grad is None for grad in gradients_of_discriminator):
    print("Warning: Some discriminator gradients are None")

# Apply gradients
generator_optimizer.apply_gradients(zip(gradients_of_generator, generator.trainable_variables))
discriminator_optimizer.apply_gradients(zip(gradients_of_discriminator, discriminator.trainable_variables))

return d_loss, g_loss

# Training Loop
for epoch in range(epochs):
    d_losses = []
    g_losses = []
    num_batches = len(photo_data) // batch_size
    for batch_i in range(num_batches):
        # Get batch data
        idx_monet = np.random.randint(0, monet_data.shape[0], batch_size)
        real_images = monet_data[idx_monet]
        real_images = tf.convert_to_tensor(real_images, dtype=tf.float32)

        idx_photo = np.random.randint(0, photo_data.shape[0], batch_size)
        images = photo_data[idx_photo]
        images = tf.convert_to_tensor(images, dtype=tf.float32)

        # Train step
        d_loss, g_loss = train_step(real_images, images)
        d_losses.append(d_loss)
        g_losses.append(g_loss)

    # Epoch summary
    d_loss_avg = tf.reduce_mean(d_losses)
    g_loss_avg = tf.reduce_mean(g_losses)
    print(f"Epoch {epoch+1}/{epochs} completed. [D loss: {d_loss_avg:.4f}] [G loss: {g_loss_avg:.4f}]")

```

## Start Training

```

In [14]: epochs = 50
         batch_size = 16

```

```
train_gan(generator, discriminator, epochs, batch_size)
```

```
Epoch 1/50 completed. [D loss: 0.9502] [G loss: 1.4353]  
Epoch 2/50 completed. [D loss: 0.6353] [G loss: 1.7227]  
Epoch 3/50 completed. [D loss: 0.6577] [G loss: 0.8371]  
Epoch 4/50 completed. [D loss: 0.6916] [G loss: 0.7293]  
Epoch 5/50 completed. [D loss: 0.6754] [G loss: 0.7493]  
Epoch 6/50 completed. [D loss: 0.6566] [G loss: 0.7430]  
Epoch 7/50 completed. [D loss: 0.6563] [G loss: 0.7528]  
Epoch 8/50 completed. [D loss: 0.6893] [G loss: 0.7571]  
Epoch 9/50 completed. [D loss: 0.6977] [G loss: 0.7260]  
Epoch 10/50 completed. [D loss: 0.6994] [G loss: 0.7228]  
Epoch 11/50 completed. [D loss: 0.7029] [G loss: 0.7087]  
Epoch 12/50 completed. [D loss: 0.6976] [G loss: 0.7072]  
Epoch 13/50 completed. [D loss: 0.6958] [G loss: 0.7155]  
Epoch 14/50 completed. [D loss: 0.6960] [G loss: 0.7168]  
Epoch 15/50 completed. [D loss: 0.6967] [G loss: 0.7132]  
Epoch 16/50 completed. [D loss: 0.6957] [G loss: 0.7153]  
Epoch 17/50 completed. [D loss: 0.6973] [G loss: 0.7033]  
Epoch 18/50 completed. [D loss: 0.6968] [G loss: 0.7066]  
Epoch 19/50 completed. [D loss: 0.6959] [G loss: 0.7033]  
Epoch 20/50 completed. [D loss: 0.6933] [G loss: 0.7109]  
Epoch 21/50 completed. [D loss: 0.6946] [G loss: 0.7052]  
Epoch 22/50 completed. [D loss: 0.6959] [G loss: 0.7044]  
Epoch 23/50 completed. [D loss: 0.6940] [G loss: 0.7064]  
Epoch 24/50 completed. [D loss: 0.6930] [G loss: 0.7074]  
Epoch 25/50 completed. [D loss: 0.6927] [G loss: 0.7061]  
Epoch 26/50 completed. [D loss: 0.6941] [G loss: 0.7056]  
Epoch 27/50 completed. [D loss: 0.6955] [G loss: 0.7005]  
Epoch 28/50 completed. [D loss: 0.6949] [G loss: 0.6982]  
Epoch 29/50 completed. [D loss: 0.6940] [G loss: 0.7026]  
Epoch 30/50 completed. [D loss: 0.6952] [G loss: 0.6996]  
Epoch 31/50 completed. [D loss: 0.6947] [G loss: 0.7058]  
Epoch 32/50 completed. [D loss: 0.6948] [G loss: 0.6987]  
Epoch 33/50 completed. [D loss: 0.6946] [G loss: 0.6976]  
Epoch 34/50 completed. [D loss: 0.6952] [G loss: 0.7004]  
Epoch 35/50 completed. [D loss: 0.6948] [G loss: 0.6972]  
Epoch 36/50 completed. [D loss: 0.6943] [G loss: 0.7009]  
Epoch 37/50 completed. [D loss: 0.6938] [G loss: 0.7003]  
Epoch 38/50 completed. [D loss: 0.6951] [G loss: 0.6977]  
Epoch 39/50 completed. [D loss: 0.6946] [G loss: 0.6973]  
Epoch 40/50 completed. [D loss: 0.6941] [G loss: 0.6980]  
Epoch 41/50 completed. [D loss: 0.6945] [G loss: 0.7030]  
Epoch 42/50 completed. [D loss: 0.6939] [G loss: 0.6988]  
Epoch 43/50 completed. [D loss: 0.6943] [G loss: 0.6965]  
Epoch 44/50 completed. [D loss: 0.6941] [G loss: 0.6979]  
Epoch 45/50 completed. [D loss: 0.6936] [G loss: 0.6985]  
Epoch 46/50 completed. [D loss: 0.6947] [G loss: 0.6951]  
Epoch 47/50 completed. [D loss: 0.6935] [G loss: 0.6999]  
Epoch 48/50 completed. [D loss: 0.6944] [G loss: 0.6970]  
Epoch 49/50 completed. [D loss: 0.6947] [G loss: 0.6963]  
Epoch 50/50 completed. [D loss: 0.6940] [G loss: 0.6975]
```

## Generating Monet-Style Images



```
In [15]: def generate_images(generator, test_input):
    prediction = generator.predict(test_input)
    plt.figure(figsize=(12, 12))

    for i in range(len(prediction)):
        plt.subplot(1, len(prediction), i+1)
        plt.imshow((prediction[i] * 0.5 + 0.5))
        plt.axis('off')
    plt.show()

    # Select a few photos to translate
    test_photos = photo_data[:5]
    generate_images(generator, test_photos)
```

1/1 [=====] - 0s 369ms/step



## Saving Generated Images

```
In [16]: import cv2

    output_path = 'generated_images/'
    os.makedirs(output_path, exist_ok=True)

    for i in range(len(photo_data)):
        img = np.expand_dims(photo_data[i], axis=0)
        gen_img = generator.predict(img)
        gen_img = (gen_img[0] * 127.5 + 127.5).astype(np.uint8)
        cv2.imwrite(os.path.join(output_path, f'monet_{i}.jpg'), cv2.cvtColor(gen_img,
        print(f"Generated images saved to {output_path}")
```

```
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Generated images saved to generated\_images/

## Discussion and Conclusion

In this project, we successfully built and trained a Generative Adversarial Network to generate images in the style of Monet. The generator learned to translate photos into Monet-style paintings, capturing the characteristic brush strokes and color palettes.

### Challenges:

- **Training Stability:** GANs can be difficult to train due to the delicate balance between the generator and discriminator.
- **Data Size:** The quality of generated images can improve with more training data and longer training times.

## Future Work:

- **Model Refinement:** Experiment with different architectures and hyperparameters to improve the quality of the generated images.
- **Evaluation Metrics:** Implement metrics like the Fréchet Inception Distance (FID) to quantitatively assess the quality of generated images.

## References

- Goodfellow, I. et al. (2014). Generative Adversarial Nets.
- Zhu, J. et al. (2017). Unpaired Image-to-Image Translation using Cycle-Consistent Adversarial Networks.