For this task we will use neural style transfer as an optimization technique used to take two images—a content image and a style reference image and blend them together so the output image looks like the content image, but “painted” in the style of the style reference image.

In [1]:

```
import os
import tensorflow as tf
# Load compressed models from tensorflow_hub
os.environ['TFHUB_MODEL_LOAD_FORMAT'] = 'COMPRESSED'
```

1. Import libraries

In [2]:

```
import IPython.display as display

import matplotlib.pyplot as plt
import matplotlib as mpl
mpl.rcParams['figure.figsize'] = (12, 12)
mpl.rcParams['axes.grid'] = False

import numpy as np
import PIL.Image
import time
import functools
```

In [3]:

```
def tensor_to_image1(tensor):
  tensor = tensor*255
  tensor = np.array(tensor, dtype=np.uint8)
  if np.ndim(tensor)>3:
    assert tensor.shape[0] == 1
    tensor = tensor[0]
  return PIL.Image.fromarray(tensor)
```

In [4]:

```
def tensor_to_image2(tensor):
  tensor = tensor*255
  tensor = np.array(tensor, dtype=np.uint8)
  if np.ndim(tensor)>3:
    assert tensor.shape[0] == 1
    tensor = tensor[0]
  return PIL.Image.fromarray(tensor)
```

2. Download and definte the content and style images

Will have two content and style images to transform.

In [5]:

```
content_path1 = tf.keras.utils.get_file('administration-buildings.jpg',
```

Loading [MathJax]/extensions/Safe.js

```
ay.edu/about/files/images/photo-gallery/administration-
```

```
buildings.jpg')
content_path2 = tf.keras.utils.get_file('vbt.jpg',
'https://www.csueastbay.edu/universitycommunications/files/images/campus-photo-
gallery/vbt.jpg')
style_path1 = tf.keras.utils.get_file('31_crop.png','http://www.kokuyocamlin.com/blog/wp-
content/uploads/2018/04/31_crop.png')
style_path2 =
tf.keras.utils.get_file('35.jpg','http://http://www.kokuyocamlin.com/blog/wp-
content/uploads/2018/04/35.jpg')
```

In [6]:

```
pip install keras==2.6.*
```

```
Requirement already satisfied: keras==2.6.* in c:\users\stsc\anaconda3\envs\tensorflow1\lib\
site-packages (2.6.0)
Note: you may need to restart the kernel to use updated packages.
```

Visualize the input

Define a function to load an image and limit its maximum dimension to 512 pixels.

In [7]:

```
def load_img(path_to_img):
  max_dim = 512
  img = tf.io.read_file(path_to_img)
  img = tf.image.decode_image(img, channels=3)
  img = tf.image.convert_image_dtype(img, tf.float32)

  shape = tf.cast(tf.shape(img)[:-1], tf.float32)
  long_dim = max(shape)
  scale = max_dim / long_dim

  new_shape = tf.cast(shape * scale, tf.int32)

  img = tf.image.resize(img, new_shape)
  img = img[tf.newaxis, :]
  return img
```

Display the images

In [8]:

```
def imshow(image, title=None):
  if len(image.shape) > 3:
    image1 = tf.squeeze(image, axis=0)

  plt.imshow(image1)
  if title:
    plt.title(title)
```

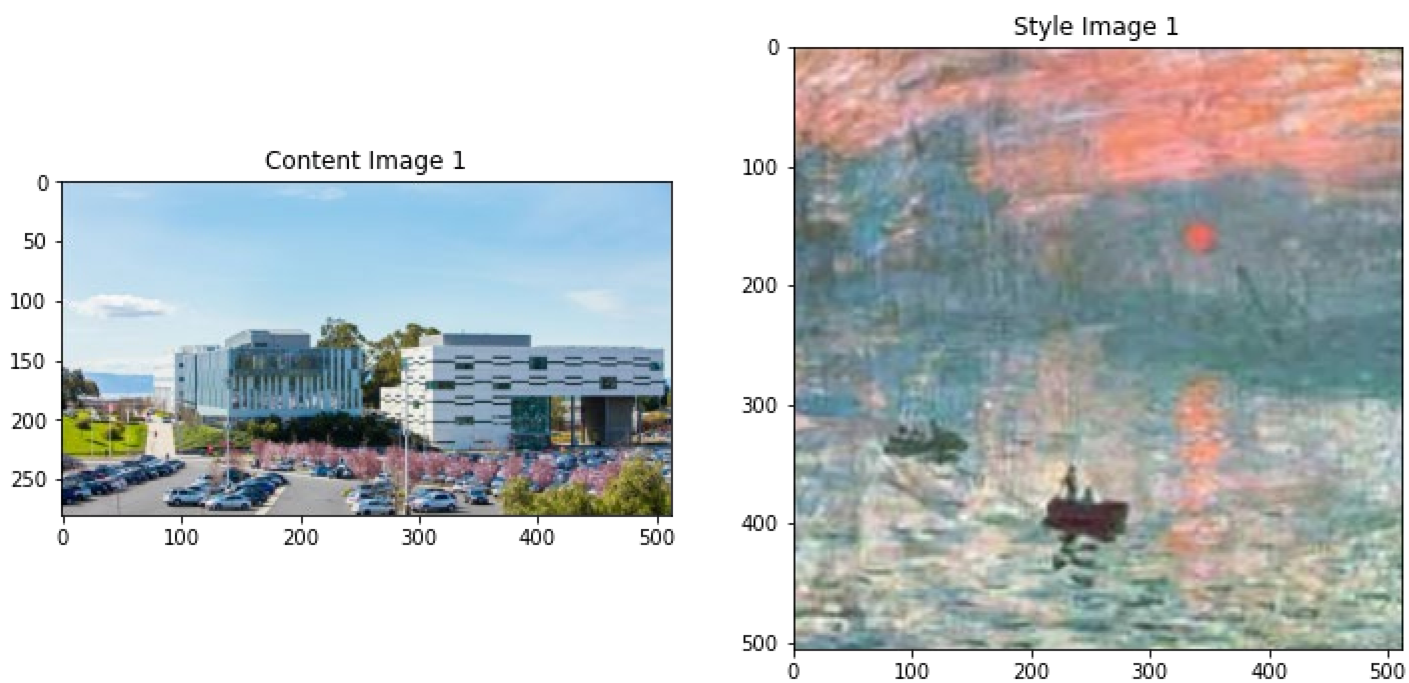
In [9]:

```
def imshow(image, title=None):
```

```
  if len(image.shape) > 3:
    image2 = tf.squeeze(image, axis=0)

  plt.imshow(image2)
  if title:
    plt.title(title)
```

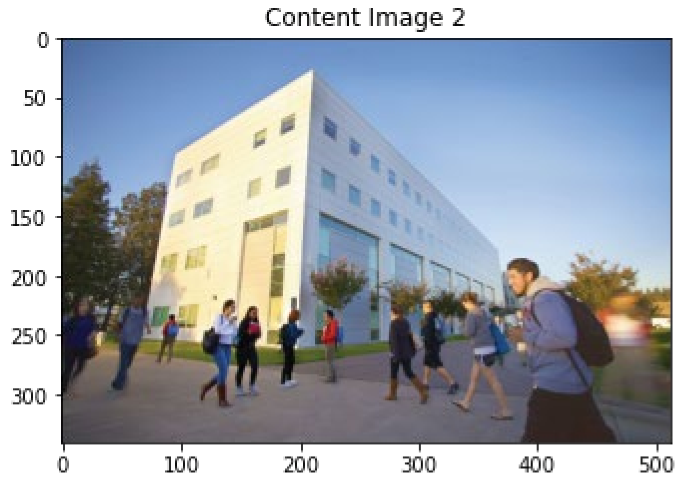
In [10]:

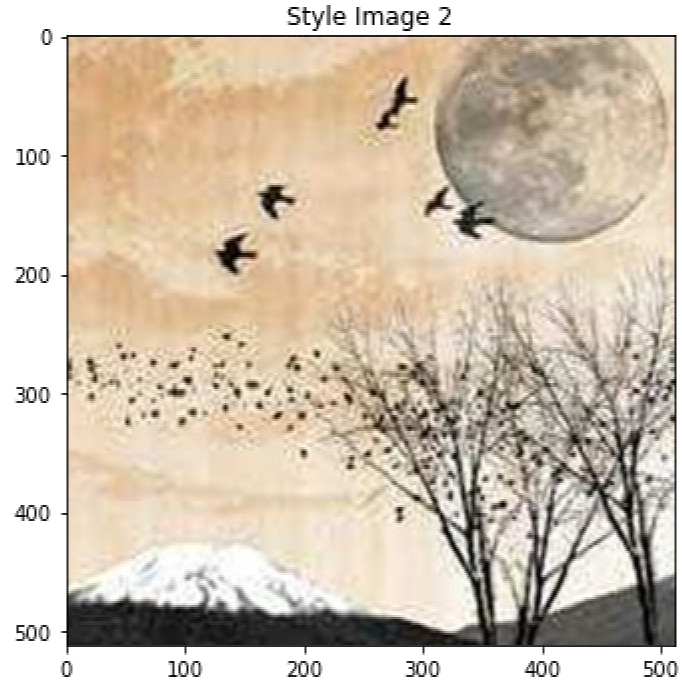
```
content_image1 = load_img('C:/Users/STSC/Downloads/administration-buildings.jpg')
style_image1 = load_img('C:/Users/STSC/Downloads/31_crop.png')


plt.subplot(1, 2, 1)
imshow(content_image1, 'Content Image 1')

plt.subplot(1, 2, 2)
imshow(style_image1, 'Style Image 1')
```



In [11]:

```
content_image2 = load_img('C:/Users/STSC/Downloads/vbt.jpg')
style_image2 = load_img('C:/Users/STSC/Downloads/35.jpg')

plt.subplot(1, 2, 1)
imshow(content_image2, 'Content Image 2')
plt.subplot(1, 2, 2)
imshow(style_image2, 'Style Image 2')
```





Style Transfer using TF-Hub

In [14]:

```
import tensorflow_hub as hub
hub_model_1 = hub.load('https://tfhub.dev/google/magenta/arbitrary-image-stylization-v1-256/2')
stylized_image1 = hub_model_1(tf.constant(content_image1), tf.constant(style_image1))[0]
tensor_to_image1(stylized_image1)
```

Out[14]:

In [15]:

```
hub_model_2 = hub.load('https://tfhub.dev/google/magenta/arbitrary-image-stylization-v1-256/2')
stylized_image2 = hub_model_2(tf.constant(content_image2), tf.constant(style_image2))[0]
tensor_to_image1(stylized_image2)
```

Out[15]:

Define content and style representation

We are using the VGG19 as a feature extractor. This is an pre-trained CNN model. We will first pass our content image through our VGG19 network. The content image will go through the feed-forward process until it reaches a deep convolutional layer in the network. The output of this layer will be the content representation of the input image.

In [16]:

```
x = tf.keras.applications.vgg19.preprocess_input(content_image1*255)
x = tf.image.resize(x, (224, 224))
vgg = tf.keras.applications.VGG19(include_top=True, weights='imagenet')
prediction_probabilities = vgg(x)
prediction_probabilities.shape
```

Out[16]:

```
TensorShape([1, 1000])
```

In [17]:

```
x = tf.keras.applications.vgg19.preprocess_input(content_image2*255)
x = tf.image.resize(x, (224, 224))
vgg = tf.keras.applications.VGG19(include_top=True, weights='imagenet')
prediction_probabilities = vgg(x)
prediction_probabilities.shape
```

Out[17]:

```
TensorShape([1, 1000])
```

In [18]:

```
predicted_top_5 =
tf.keras.applications.vgg19.decode_predictions(prediction_probabilities.numpy())[0]
[(class_name, prob) for (number, class_name, prob) in predicted_top_5]
```

Out[18]:

```
[('obelisk', 0.31247222),
 ('triumphal_arch', 0.14896436),
 ('bell_cote', 0.09479901),
 ('flagpole', 0.07189041),
 ('sundial', 0.0382116)]
```

Now load a VGG19 without the classification head, and list the layer names

In [19]:

```
vgg = tf.keras.applications.VGG19(include_top=False, weights='imagenet')

print()
for layer in vgg.layers:
  print(layer.name)
```

```
input_3
block1_conv1
block1_conv2
block1_pool
block2_conv1
block2_conv2
block2_pool
block3_conv1
block3_conv2
block3_conv3
block3_conv4
block3_pool
block4_conv1
block4_conv2
block4_conv3
block4_conv4
block4_pool
block5_conv1
block5_conv2
block5_conv3
block5_conv4
block5_pool
```

Choose intermediate layers from the network to represent the style and content of the image

In [20]:

```
content_layers1 = ['block5_conv2']

style_layers1 = ['block1_conv1',
                'block2_conv1',
                'block3_conv1',
                'block4_conv1',
                'block5_conv1']

num_content_layers1 = len(content_layers1)
num_style_layers1 = len(style_layers1)
```

In [21]:

```
content_layers2 = ['block5_conv2']

style_layers2 = ['block1_conv1',
                'block2_conv1',
```

```
                  'block3_conv1',
                  'block4_conv1',
                  'block5_conv1']

num_content_layers2 = len(content_layers2)
num_style_layers2 = len(style_layers2)
```

Build the model

To define a model using the functional API, specify the inputs and outputs:

model = Model(inputs, outputs)

This following function builds a VGG19 model that returns a list of intermediate layer outputs:

In [22]:

```
def vgg_layers(layer_names):
  """ Creates a vgg model that returns a list of intermediate output values."""
  # Load our model. Load pretrained VGG, trained on imagenet data
  vgg = tf.keras.applications.VGG19(include_top=False, weights='imagenet')
  vgg.trainable = False

  outputs = [vgg.get_layer(name).output for name in layer_names]

  model = tf.keras.Model([vgg.input], outputs)
  return model
```

In [25]:

```
style_extractor1 = vgg_layers(style_layers1)
style_outputs1 = style_extractor1(style_image1*255)

#Look at the statistics of each layer's output
for name, output in zip(style_layers1, style_outputs1):
  print(name)
  print("  shape: ", output.numpy().shape)
  print("  min: ", output.numpy().min())
  print("  max: ", output.numpy().max())
  print("  mean: ", output.numpy().mean())
  print()
```

```
block1_conv1
  shape:  (1, 506, 512, 64)
  min:  0.0
  max:  814.4532
  mean:  25.954447

block2_conv1
  shape:  (1, 253, 256, 128)
  min:  0.0
  max:  2554.938
  mean:  133.06595

block3_conv1
  shape:  (1, 126, 128, 256)
```

```
  min:  0.0
  max:  8090.989
  mean:  114.57086

block4_conv1
  shape:  (1, 63, 64, 512)
  min:  0.0
  max:  12123.175
  mean:  462.43735

block5_conv1
  shape:  (1, 31, 32, 512)
  min:  0.0
  max:  2129.4258
  mean:  31.055548
```

In [26]:

```
style_extractor2 = vgg_layers(style_layers2)
style_outputs2 = style_extractor2(style_image2*255)

#Look at the statistics of each layer's output
for name, output in zip(style_layers2, style_outputs2):
  print(name)
  print("  shape: ", output.numpy().shape)
  print("  min: ", output.numpy().min())
  print("  max: ", output.numpy().max())
  print("  mean: ", output.numpy().mean())
  print()
```

```
block1_conv1
  shape:  (1, 512, 512, 64)
  min:  0.0
  max:  852.4884
  mean:  33.732094

block2_conv1
  shape:  (1, 256, 256, 128)
  min:  0.0
  max:  3012.3748
  mean:  179.00308

block3_conv1
  shape:  (1, 128, 128, 256)
  min:  0.0
  max:  9174.078
  mean:  152.82521

block4_conv1
  shape:  (1, 64, 64, 512)
  min:  0.0
  max:  14814.93
  mean:  575.90955

block5_conv1
  shape:  (1, 32, 32, 512)
  min:  0.0
```

```
max:  2554.9873
mean:  39.30771
```

The correlations in each layer are given by a gram matrix. To calculate the style loss between a target and style image we find the mean squared distance between the style and target image gram matrices.

In [27]:

```
def gram_matrix(input_tensor):
  result = tf.linalg.einsum('bijc,bijd->bcd', input_tensor, input_tensor)
  input_shape = tf.shape(input_tensor)
  num_locations = tf.cast(input_shape[1]*input_shape[2], tf.float32)
  return result/(num_locations)
```

Build a model that returns the style and content tensors.

In [28]:

```
class StyleContentModel1(tf.keras.models.Model):
  def __init__(self, style_layers1, content_layers1):
    super(StyleContentModel1, self).__init__()
    self.vgg = vgg_layers(style_layers1 + content_layers1)
    self.style_layers1 = style_layers1
    self.content_layers1 = content_layers1
    self.num_style_layers1 = len(style_layers1)
    self.vgg.trainable = False

  def call(self, inputs):
    "Expects float input in [0,1]"
    inputs = inputs*255.0
    preprocessed_input = tf.keras.applications.vgg19.preprocess_input(inputs)
    outputs = self.vgg(preprocessed_input)
    style_outputs1, content_outputs1 = (outputs[:self.num_style_layers1],
                                        outputs[self.num_style_layers1:])

    style_outputs1 = [gram_matrix(style_output1)
                     for style_output1 in style_outputs1]

    content_dict1 = {content_name: value
                    for content_name, value
                    in zip(self.content_layers1, content_outputs1)}

    style_dict1 = {style_name: value
                  for style_name, value
                  in zip(self.style_layers1, style_outputs1)}

    return {'content': content_dict1, 'style': style_dict1}
```

In [34]:

```
class StyleContentModel2(tf.keras.models.Model):
  def __init__(self, style_layers2, content_layers2):
    super(StyleContentModel2, self).__init__()
    self.vgg = vgg_layers(style_layers2+ content_layers2)
    self.style_layers2 = style_layers2
    self.content_layers2 = content_layers2
    self.num_style_layers2 = len(style_layers2)
    self.vgg.trainable = False
```

```
    def call(self, inputs):
      "Expects float input in [0,1]"
      inputs = inputs*255.0
      preprocessed_input = tf.keras.applications.vgg19.preprocess_input(inputs)
      outputs = self.vgg(preprocessed_input)
      style_outputs2, content_outputs2 = (outputs[:self.num_style_layers2],
                                          outputs[self.num_style_layers2:])

      style_outputs2 = [gram_matrix(style_output2)
                       for style_output2 in style_outputs2]

      content_dict2 = {content_name: value
                      for content_name, value
                      in zip(self.content_layers2, content_outputs2)}

      style_dict2 = {style_name: value
                    for style_name, value
                    in zip(self.style_layers2, style_outputs2)}

      return {'content': content_dict2, 'style': style_dict2}
```

When called on an image, this model returns the gram matrix (style) of the style_layers and content of the content_layers:

In [35]:

```
extractor1 = StyleContentModel1(style_layers1, content_layers1)

results1 = extractor1(tf.constant(content_image1))

print('Styles:')
for name, output in sorted(results1['style'].items()):
  print("  ", name)
  print("    shape: ", output.numpy().shape)
  print("    min: ", output.numpy().min())
  print("    max: ", output.numpy().max())
  print("    mean: ", output.numpy().mean())
  print()

print("Contents:")
for name, output in sorted(results1['content'].items()):
  print("  ", name)
  print("    shape: ", output.numpy().shape)
  print("    min: ", output.numpy().min())
  print("    max: ", output.numpy().max())
  print("    mean: ", output.numpy().mean())
```

```
Styles:
   block1_conv1
    shape:  (1, 64, 64)
    min:  0.15682442
    max:  57264.18
    mean:  774.34607

   block2_conv1
    shape:  (1, 128, 128)
    min:  0.0
    max:  164467.44
    mean:  21473.328
```

```
    block3_conv1
     shape:  (1, 256, 256)
     min:  0.0
     max:  440160.62
     mean:  20256.805

    block4_conv1
     shape:  (1, 512, 512)
     min:  0.0
     max:  5367246.5
     mean:  290062.03

    block5_conv1
     shape:  (1, 512, 512)
     min:  0.0
     max:  127718.03
     mean:  2189.627

Contents:
    block5_conv2
     shape:  (1, 17, 32, 512)
     min:  0.0
     max:  1119.1691
     mean:  15.730705
```

In [36]:

```
extractor2 = StyleContentModel2(style_layers2, content_layers2)

results2 = extractor2(tf.constant(content_image2))

print('Styles:')
for name, output in sorted(results2['style'].items()):
  print("  ", name)
  print("    shape: ", output.numpy().shape)
  print("    min: ", output.numpy().min())
  print("    max: ", output.numpy().max())
  print("    mean: ", output.numpy().mean())
  print()

print("Contents:")
for name, output in sorted(results2['content'].items()):
  print("  ", name)
  print("    shape: ", output.numpy().shape)
  print("    min: ", output.numpy().min())
  print("    max: ", output.numpy().max())
  print("    mean: ", output.numpy().mean())
```

```
Styles:
    block1_conv1
     shape:  (1, 64, 64)
     min:  0.02921539
     max:  36354.13
     mean:  484.12726

    block2_conv1
     shape:  (1, 128, 128)
```

```
    min:  0.0
    max:  74700.19
    mean:  12216.603

   block3_conv1
    shape:  (1, 256, 256)
    min:  0.0
    max:  194858.22
    mean:  13821.968

   block4_conv1
    shape:  (1, 512, 512)
    min:  0.0
    max:  3501470.8
    mean:  191234.78

   block5_conv1
    shape:  (1, 512, 512)
    min:  0.0
    max:  142621.88
    mean:  2038.3378

Contents:
   block5_conv2
    shape:  (1, 21, 32, 512)
    min:  0.0
    max:  1832.9955
    mean:  17.024118
```

Implement the style transfer algorithm. Do this by calculating the mean square error for your image's output relative to each target, then take the weighted sum of these losses.

In [37]:

```
style_targets1 = extractor1(style_image1)['style']
content_targets1 = extractor1(content_image1)['content']
```

In [38]:

```
style_targets2 = extractor2(style_image2)['style']
content_targets2 = extractor2(content_image2)['content']
```

Defining a tf.Variable to contain the image to optimize.

In [39]:

```
image1 = tf.Variable(content_image1)
```

In [40]:

```
image2 = tf.Variable(content_image2)
```

Since this is a float image, define a function to keep the pixel values between 0 and 1:

In [41]:

```
def clip_0_1(image1):
  return tf.clip_by_value(image1, clip_value_min=0.0, clip_value_max=1.0)
```

In [42]:

```
def clip_0_1(image2):
  return tf.clip_by_value(image2, clip_value_min=0.0, clip_value_max=1.0)
```

Create an optimizer: Adam

In [43]:

```
opt = tf.optimizers.Adam(learning_rate=0.02, beta_1=0.99, epsilon=1e-1)
```

To optimize this, use a weighted combination of the two losses to get the total loss:

In [1]:

```
style_weight=1e-2
content_weight=1e4
```

In [45]:

```
def style_content_loss1(outputs1):
    style_outputs1 = outputs1['style']
    content_outputs1 = outputs1['content']
    style_loss1 = tf.add_n([tf.reduce_mean((style_outputs1[name]-style_targets1[name])**2)
                           for name in style_outputs1.keys()])
    style_loss1 *= style_weight / num_style_layers1

    content_loss1 =
tf.add_n([tf.reduce_mean((content_outputs1[name]-content_targets1[name])**2)
                             for name in content_outputs1.keys()])
    content_loss1 *= content_weight / num_content_layers1
    loss1 = style_loss1 + content_loss1
    return loss1
```

In [46]:

```
def style_content_loss2(outputs2):
    style_outputs2 = outputs2['style']
    content_outputs2 = outputs2['content']
    style_loss2 = tf.add_n([tf.reduce_mean((style_outputs2[name]-style_targets2[name])**2)
                           for name in style_outputs2.keys()])
    style_loss2 *= style_weight / num_style_layers2

    content_loss2 =
tf.add_n([tf.reduce_mean((content_outputs2[name]-content_targets2[name])**2)
                             for name in content_outputs2.keys()])
    content_loss2 *= content_weight / num_content_layers2
    loss2 = style_loss2 + content_loss2
    return loss2
```

Use tf.GradientTape to update the image.

In [47]:

```
@tf.function()
def train_step1(image1):
  with tf.GradientTape() as tape:
    outputs1 = extractor1(image1)
    loss1 = style_content_loss1(outputs1)

  grad1 = tape.gradient(loss1, image1)
  opt.apply_gradients([(grad1, image1)])
```

```
  image1.assign(clip_0_1(image1))
```

In [48]:

```
@tf.function()
def train_step2(image2):
  with tf.GradientTape() as tape:
    outputs2 = extractor1(image2)
    loss2 = style_content_loss2(outputs2)

  grad2 = tape.gradient(loss2, image2)
  opt.apply_gradients([(grad2, image2)])
  image2.assign(clip_0_1(image2))
```

Run a few steps to test

In [50]:

```
train_step1(image1)
train_step1(image1)
train_step1(image1)
tensor_to_image1(image1)
```

Out[50]:

In [ ]:

In [51]:

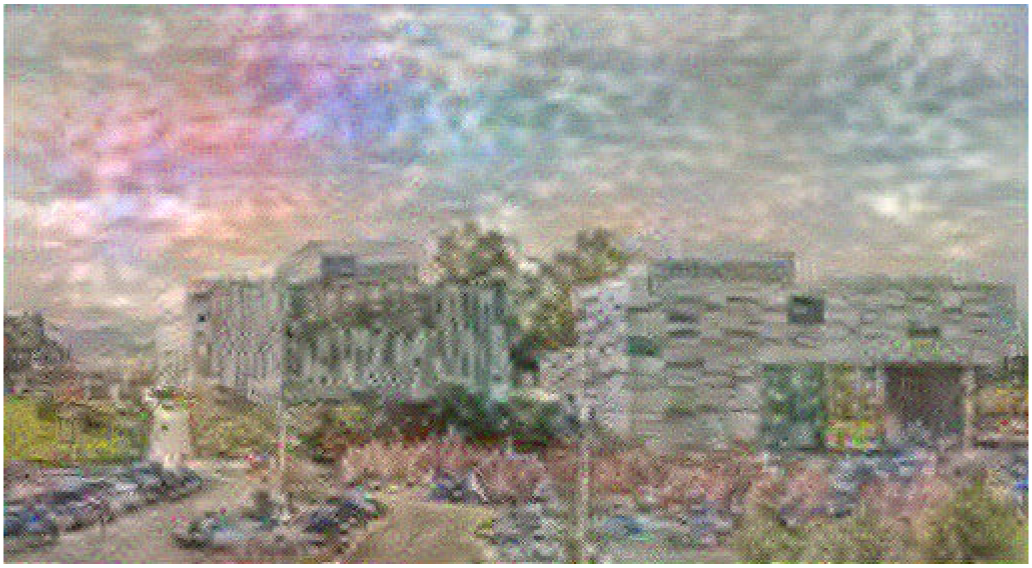
```
train_step2(image2)
train_step2(image2)
train_step2(image2)
tensor_to_image2(image2)
```

Out[51]:

Since it's working, perform a longer optimization:

In [54]:

```
import time
start = time.time()

epochs = 10
steps_per_epoch = 100

step = 0
for n in range(epochs):
  for m in range(steps_per_epoch):
    step += 1
    train_step1(image1)
    print(".", end='', flush=True)
  display.clear_output(wait=True)
  display.display(tensor_to_image1(image1))
  print("Train step: {}".format(step))

end = time.time()
print("Total time: {:.1f}".format(end-start))
```



```
Train step: 1000
Total time: 1498.5
```

In [55]:

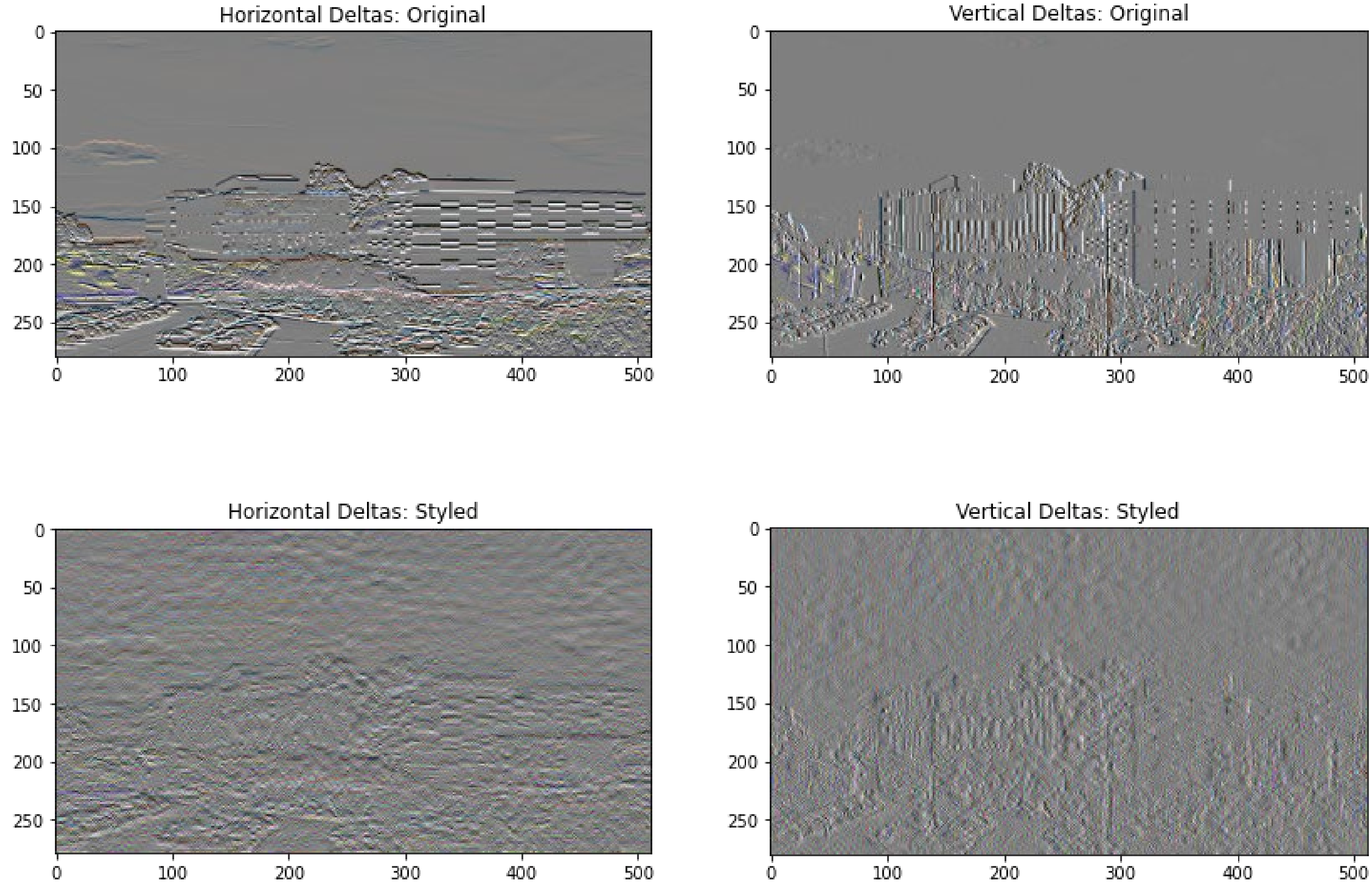
```
import time
start = time.time()

epochs = 10
steps_per_epoch = 100

step = 0
for n in range(epochs):
  for m in range(steps_per_epoch):
    step += 1
    train_step2(image2)
    print(".", end='', flush=True)
  display.clear_output(wait=True)
  display.display(tensor_to_image2(image2))
  print("Train step: {}".format(step))

end = time.time()
print("Total time: {:.1f}".format(end-start))
```

```
Train step: 1000
Total time: 1789.0
```

The model produces a lot of high frequency artifacts. We are going to decrease these using regularization term on the high frequency components of the image. Total variation loss:

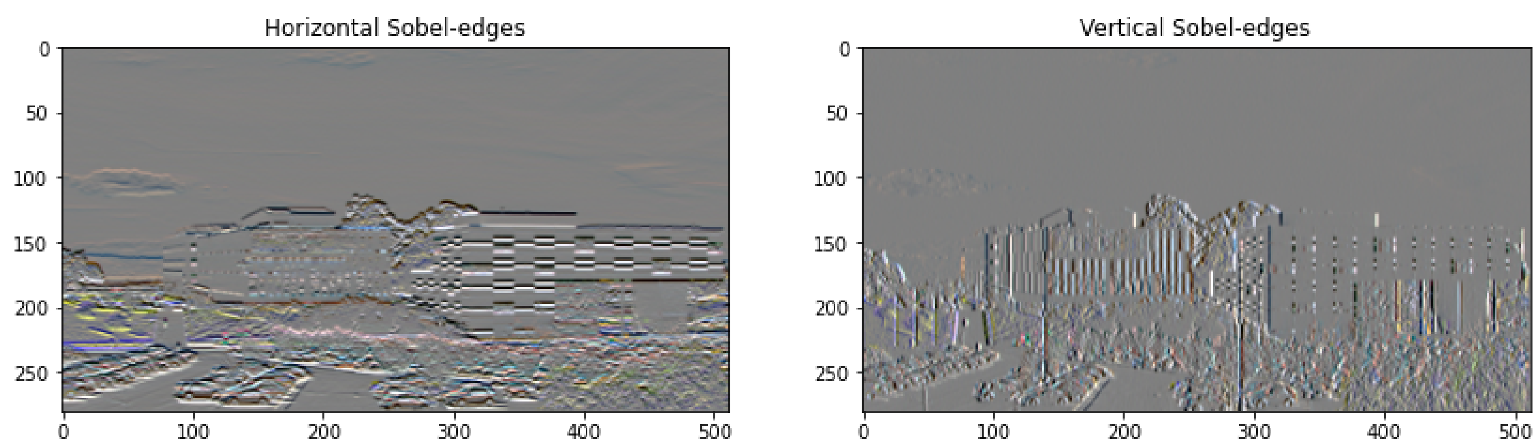
In [57]:

```
def high_pass_x_y1(image1):
  x_var1 = image1[:, :, 1:, :] - image1[:, :, :-1, :]
  y_var1 = image1[:, 1:, :, :] - image1[:, :-1, :, :]

  return x_var1, y_var1

x_deltas1, y_deltas1 = high_pass_x_y1(content_image1)

plt.figure(figsize=(14, 10))
plt.subplot(2, 2, 1)
imshow(clip_0_1(2*y_deltas1+0.5), "Horizontal Deltas: Original")

plt.subplot(2, 2, 2)
imshow(clip_0_1(2*x_deltas1+0.5), "Vertical Deltas: Original")

x_deltas1, y_deltas1 = high_pass_x_y1(image1)

plt.subplot(2, 2, 3)
imshow(clip_0_1(2*y_deltas1+0.5), "Horizontal Deltas: Styled")

plt.subplot(2, 2, 4)
imshow(clip_0_1(2*x_deltas1+0.5), "Vertical Deltas: Styled")
```



In [58]:

```
plt.figure(figsize=(14, 10))

sobel1 = tf.image.sobel_edges(content_image1)
plt.subplot(1, 2, 1)
imshow(clip_0_1(sobel1[..., 0]/4+0.5), "Horizontal Sobel-edges")
plt.subplot(1, 2, 2)
imshow(clip_0_1(sobel1[..., 1]/4+0.5), "Vertical Sobel-edges")
```



In [59]:

```
def total_variation_loss1(image1):
```

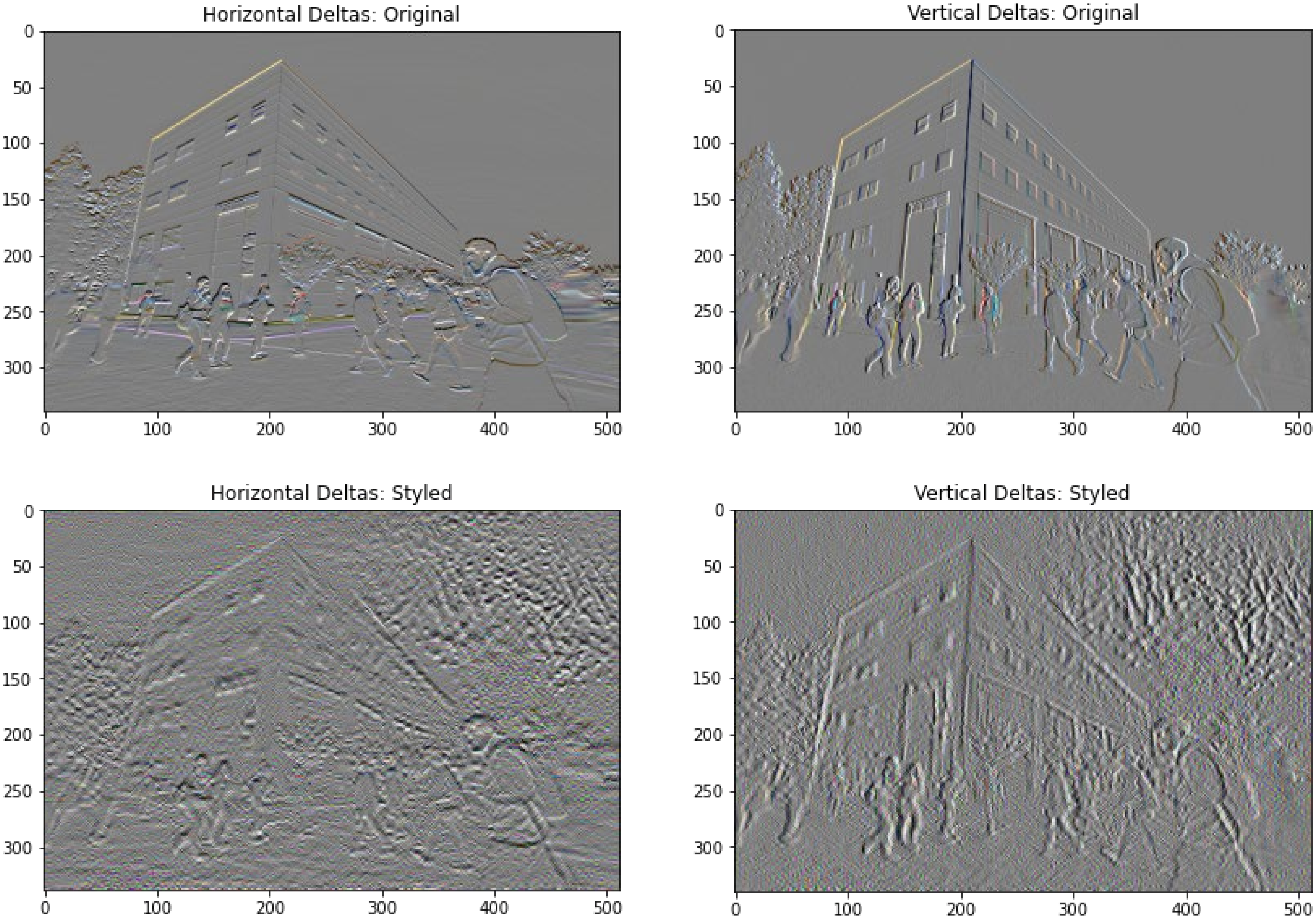
```
  x_deltas1, y_deltas1 = high_pass_x_y1(image1)
  return tf.reduce_sum(tf.abs(x_deltas1)) + tf.reduce_sum(tf.abs(y_deltas1))

total_variation_loss1(image1).numpy()
```

Out[59]:

```
62046.836
```

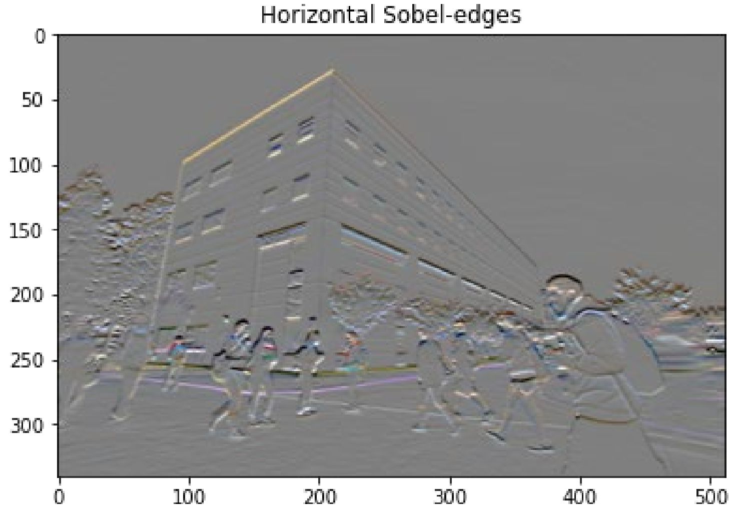
In [60]:

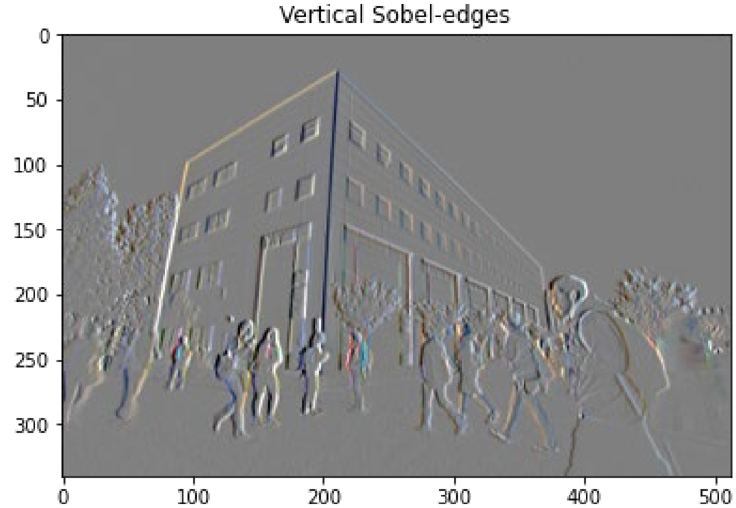
```
def high_pass_x_y2(image2):
  x_var2 = image2[:, :, 1:, :] - image2[:, :, :-1, :]
  y_var2 = image2[:, 1:, :, :] - image2[:, :-1, :, :]

  return x_var2, y_var2

x_deltas2, y_deltas2 = high_pass_x_y2(content_image2)

plt.figure(figsize=(14, 10))
plt.subplot(2, 2, 1)
imshow(clip_0_1(2*y_deltas2+0.5), "Horizontal Deltas: Original")

plt.subplot(2, 2, 2)
imshow(clip_0_1(2*x_deltas2+0.5), "Vertical Deltas: Original")

x_deltas2, y_deltas2 = high_pass_x_y2(image2)

plt.subplot(2, 2, 3)
imshow(clip_0_1(2*y_deltas2+0.5), "Horizontal Deltas: Styled")

plt.subplot(2, 2, 4)
imshow(clip_0_1(2*x_deltas2+0.5), "Vertical Deltas: Styled")
```



In [61]:

```
plt.figure(figsize=(14, 10))

sobel2 = tf.image.sobel_edges(content_image2)
plt.subplot(1, 2, 1)
imshow(clip_0_1(sobel2[..., 0]/4+0.5), "Horizontal Sobel-edges")
plt.subplot(1, 2, 2)
imshow(clip_0_1(sobel2[..., 1]/4+0.5), "Vertical Sobel-edges")
```





In [62]:

```
def total_variation_loss2(image2):
  x_deltas2, y_deltas2 = high_pass_x_y2(image2)
  return tf.reduce_sum(tf.abs(x_deltas2)) + tf.reduce_sum(tf.abs(y_deltas2))

total_variation_loss2(image2).numpy()
```

Out[62]:

```
91396.95
```

In [63]:

```
tf.image.total_variation(image1).numpy()
```

Out[63]:

```
array([62046.836], dtype=float32)
```

In [64]:

```
tf.image.total_variation(image2).numpy()
```

Out[64]:

```
array([91396.95], dtype=float32)
```

Re-run the optimization Choose a weight for the total_variation_loss:

In [65]:

```
total_variation_weight=30
```

Now include it in the train_step function:

In [86]:

```
@tf.function()
def train_step1(image1):
  with tf.GradientTape() as tape:
    outputs1 = extractor1(image1)
    loss1 = style_content_loss1(outputs1)
    loss1 += total_variation_weight*tf.image.total_variation(image1)

  grad1 = tape.gradient(loss1, image1)
  opt.apply_gradients([(grad1, image1)])
  image1.assign(clip_0_1(image1))
```

In [87]:

```
@tf.function()
def train_step2(image2):
  with tf.GradientTape() as tape:
    outputs2 = extractor2(image2)
    loss2 = style_content_loss2(outputs2)
    loss2 += total_variation_weight*tf.image.total_variation(image2)

  grad2 = tape.gradient(loss2, image2)
  opt.apply_gradients([(grad2, image2)])
  image2.assign(clip_0_1(image2))
```

Reinitialize the optimization variable:

In [88]:

```
image1 = tf.Variable(content_image1)
```

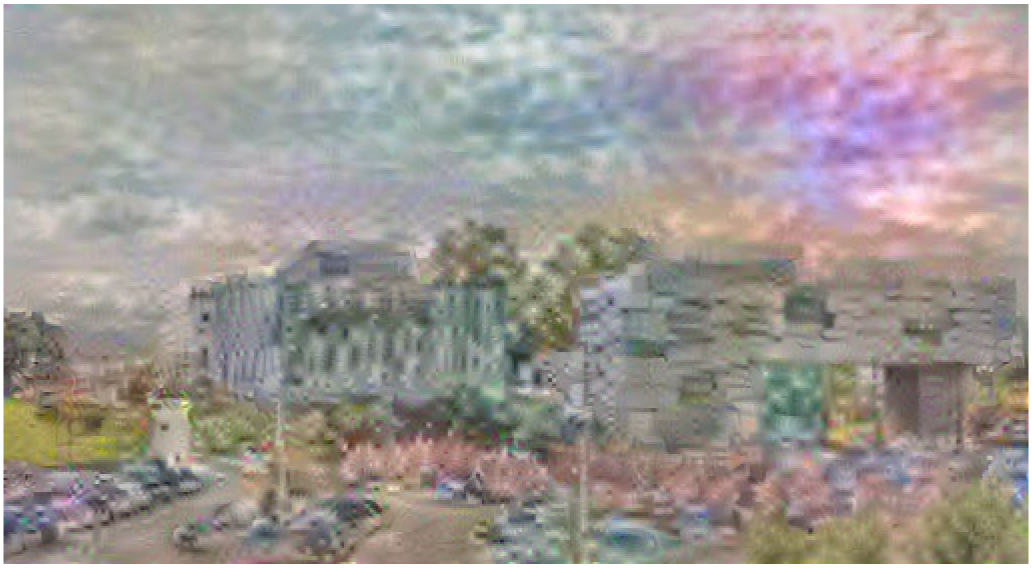
In [89]:

```
image2 = tf.Variable(content_image2)
```

And run the optimization

In [90]:

```
import time
start = time.time()

epochs = 10
steps_per_epoch = 100

step = 0
for n in range(epochs):
  for m in range(steps_per_epoch):
    step += 1
    train_step1(image1)
    print(".", end='', flush=True)
  display.clear_output(wait=True)
  display.display(tensor_to_image1(image1))
  print("Train step: {}".format(step))

end = time.time()
print("Total time: {:.1f}".format(end-start))
```



```
Train step: 1000
Total time: 1479.6
```

In [94]:

```
import time
start = time.time()

epochs = 10
steps_per_epoch = 100

step = 0
for n in range(epochs):
  for m in range(steps_per_epoch):
    step += 1
    train_step2(image2)
    print(".", end='', flush=True)
  display.clear_output(wait=True)
  display.display(tensor_to_image2(image2))
  print("Train step: {}".format(step))

end = time.time()
print("Total time: {:.1f}".format(end-start))
```

```
Train step: 1000
Total time: 1781.3
```

Save the result

In [92]:

```
file_name1 = 'stylized-image1.png'
tensor_to_image1(image1).save(file_name1)

try:
  from google.colab import files
except ImportError:
   pass
else:
  files.download(file_name)
```

In [93]:

```
file_name2 = 'stylized-image2.png'
tensor_to_image2(image2).save(file_name2)

try:
  from google.colab import files
except ImportError:
   pass
else:
  files.download(file_name)
```

In [ ]: