```
from __future__ import absolute_import, division, print_function, unicode_literals
```

```
#!pip install -q tensorflow-gpu==2.0.0-beta1
import tensorflow as tf

# Generating plots of attention in order to see which parts of an image
# This model focuses on during captioning
import matplotlib.pyplot as plt

# Scikit-learn includes many helpful utilities
from sklearn.model_selection import train_test_split
from sklearn.utils import shuffle

import re
import numpy as np
import os
import time
import json
from glob import glob
from PIL import Image
import pickle
```

```
annotation_zip = tf.keras.utils.get_file('captions.zip',
                                          cache_subdir=os.path.abspath('.'),
                                          origin = 'http://images.cocodataset.org/annotations/annotations_trainval2014.zip',
                                          extract = True)
annotation_file = os.path.dirname(annotation_zip)+'/annotations/captions_train2014.json'

name_of_zip = 'train2014.zip'
if not os.path.exists(os.path.abspath('.') + '/' + name_of_zip):
  image_zip = tf.keras.utils.get_file(name_of_zip,
                                      cache_subdir=os.path.abspath('.'),
                                      origin = 'http://images.cocodataset.org/zips/train2014.zip',
                                      extract = True)
                                     '/train2014/'
else:
  PATH = os.path.abspath('.')+'/train2014/'
```



```
Downloading data from http://images.cocodataset.org/annotations/annotations_trainval2014.zip
252872794/252872794 [==============================] - 6s 0us/step
Downloading data from http://images.cocodataset.org/zips/train2014.zip
13510573713/13510573713 [==============================] - 790s 0us/step
```

```
# Read the json file
with open(annotation_file, 'r') as f:
    annotations = json.load(f)

# Store captions and image names in vectors
all_captions = []
all_img_name_vector = []

for annot in annotations['annotations']:
    caption = '<start> ' + annot['caption'] + ' <end>'
    image_id = annot['image_id']
```

```
    full_coco_image_path = PATH + 'COCO_train2014_' + '%012d.jpg' % (image_id)

    all_img_name_vector.append(full_coco_image_path)
    all_captions.append(caption)

# Shuffle captions and image_names together
# Set a random state
train_captions, img_name_vector = shuffle(all_captions,
                                          all_img_name_vector,
                                          random_state=1)

# Selecting the first 30000 captions from the shuffled set
num_examples = 30000
train_captions = train_captions[:num_examples]
img_name_vector = img_name_vector[:num_examples]
```

+ Code + Text

```
len(train_captions), len(all_captions)
```

```
(30000, 414113)
```

```
def load_image(image_path):
    img = tf.io.read_file(image_path)
    img = tf.image.decode_jpeg(img, channels=3)
    img = tf.image.resize(img, (299, 299))
    img = tf.keras.applications.inception_v3.preprocess_input(img)
    return img, image_path
```

```
image_model = tf.keras.applications.InceptionV3(include_top=False,
                                                weights='imagenet')
new_input = image_model.input
hidden_layer = image_model.layers[-1].output

image_features_extract_model = tf.keras.Model(new_input, hidden_layer)
```

Saved successfully!

```
torage.googleapis.com/tensorflow/keras-applications/inception_v3/inception_v3_weights_tf_dim_ordering_tf_kernels_notop.h5
=================] - 0s 0us/step
```

```
!pip install -q tqdm
```

```
from tqdm import tqdm
```

```
for img, path in image_dataset:
```

```
  File "<ipython-input-10-8307f525ae98>", line 1
    for img, path in image_dataset:
                                   ^
SyntaxError: unexpected EOF while parsing
```

SEARCH STACK OVERFLOW

```
# Get unique images
encode_train = sorted(set(img_name_vector))
```

```
image_dataset = tf.data.Dataset.from_tensor_slices(encode_train)
image_dataset = image_dataset.map(
  load_image, num_parallel_calls=tf.data.experimental.AUTOTUNE).batch(16)

for img, path in image_dataset:
  batch_features = image_features_extract_model(img)
  batch_features = tf.reshape(batch_features,
                              (batch_features.shape[0], -1, batch_features.shape[3]))

  for bf, p in zip(batch_features, path):
    path_of_feature = p.numpy().decode("utf-8")
    np.save(path_of_feature, bf.numpy())

# Finding the maximum length of any caption in our dataset
def calc_max_length(tensor):
    return max(len(t) for t in tensor)



# Choosing the top 5000 words from the vocabulary
top_k = 5000
tokenizer = tf.keras.preprocessing.text.Tokenizer(num_words=top_k,
                                                  oov_token="",
                                                  filters='!"#$%&()*+.,-/:;=?@[\]^_`{|}~ ')
tokenizer.fit_on_texts(train_captions)
train_seqs = tokenizer.texts_to_sequences(train_captions)



tokenizer.word_index[''] = 0
tokenizer.index_word[0] = ''


# Creating the tokenized vectors
train_seqs = tokenizer.texts_to_sequences(train_captions)
```



```
                                    of the captions
                                    sequence.pad_sequences(train_seqs, padding='post')

# Calculates the max_length, which is used to store the attention weights
max_length = calc_max_length(train_seqs)


# Create training and validation sets using an 80-20 split
img_name_train, img_name_val, cap_train, cap_val = train_test_split(img_name_vector,
                                                                    cap_vector,
                                                                    test_size=0.2,
                                                                    random_state=0)


len(img_name_train), len(cap_train), len(img_name_val), len(cap_val)


     (24000, 24000, 6000, 6000)


BATCH_SIZE = 64
BUFFER_SIZE = 1000
```

```
embedding_dim = 256
units = 512
vocab_size = len(tokenizer.word_index) + 1
num_steps = len(img_name_train) // BATCH_SIZE
# Shape of the vector extracted from InceptionV3 is (64, 2048)
# These two variables represent that vector shape
features_shape = 2048
attention_features_shape = 64

# Load the numpy files
def map_func(img_name, cap):
  img_tensor = np.load(img_name.decode('utf-8')+'.npy')
  return img_tensor, cap


dataset = tf.data.Dataset.from_tensor_slices((img_name_train, cap_train))

# Use map to load the numpy files in parallel
dataset = dataset.map(lambda item1, item2: tf.numpy_function(
          map_func, [item1, item2], [tf.float32, tf.int32]),
          num_parallel_calls=tf.data.experimental.AUTOTUNE)

# Shuffle and batch
dataset = dataset.shuffle(BUFFER_SIZE).batch(BATCH_SIZE)
dataset = dataset.prefetch(buffer_size=tf.data.experimental.AUTOTUNE)



class BahdanauAttention(tf.keras.Model):
  def __init__(self, units):
    super(BahdanauAttention, self).__init__()
    self.W1 = tf.keras.layers.Dense(units)
    self.W2 = tf.keras.layers.Dense(units)
    self.V = tf.keras.layers.Dense(1)

  def call(self, features, hidden):
    # features(CNN_encoder output) shape == (batch_size, 64, embedding_dim)

                                    idden_size)
    # hidden_with_time_axis shape == (batch_size, 1, hidden_size)
    hidden_with_time_axis = tf.expand_dims(hidden, 1)

    # score shape == (batch_size, 64, hidden_size)
    score = tf.nn.tanh(self.W1(features) + self.W2(hidden_with_time_axis))

    # attention_weights shape == (batch_size, 64, 1)
    # you get 1 at the last axis because you are applying score to self.V
    attention_weights = tf.nn.softmax(self.V(score), axis=1)

    # context_vector shape after sum == (batch_size, hidden_size)
    context_vector = attention_weights * features
    context_vector = tf.reduce_sum(context_vector, axis=1)

    return context_vector, attention_weights


class CNN_Encoder(tf.keras.Model):
    # Since we have already extracted the features and dumped it using pickle
    # This encoder passes those features through a Fully connected layer
    def __init__(self, embedding_dim):
```

```
  def __init__(self, embedding_dim):
    super(CNN_Encoder, self).__init__()
    # shape after fc == (batch_size, 64, embedding_dim)
    self.fc = tf.keras.layers.Dense(embedding_dim)

  def call(self, x):
    x = self.fc(x)
    x = tf.nn.relu(x)
    return x



class RNN_Decoder(tf.keras.Model):
 def __init__(self, embedding_dim, units, vocab_size):
  super(RNN_Decoder, self).__init__()
  self.units = units

  self.embedding = tf.keras.layers.Embedding(vocab_size, embedding_dim)
  self.gru = tf.keras.layers.GRU(self.units,
                                 return_sequences=True,
                                 return_state=True,
                                 recurrent_initializer='glorot_uniform')
  self.fc1 = tf.keras.layers.Dense(self.units)
  self.fc2 = tf.keras.layers.Dense(vocab_size)

  self.attention = BahdanauAttention(self.units)

 def call(self, x, features, hidden):
  # defining attention as a separate model
  context_vector, attention_weights = self.attention(features, hidden)

  # x shape after passing through embedding == (batch_size, 1, embedding_dim)
  x = self.embedding(x)

  # x shape after concatenation == (batch_size, 1, embedding_dim + hidden_size)
  x = tf.concat([tf.expand_dims(context_vector, 1), x], axis=-1)

                r to the GRU


  # shape == (batch_size, max_length, hidden_size)
  x = self.fc1(output)

  # x shape == (batch_size * max_length, hidden_size)
  x = tf.reshape(x, (-1, x.shape[2]))

  # output shape == (batch_size * max_length, vocab)
  x = self.fc2(x)

  return x, state, attention_weights

 def reset_state(self, batch_size):
  return tf.zeros((batch_size, self.units))


encoder = CNN_Encoder(embedding_dim)
decoder = RNN_Decoder(embedding_dim, units, vocab_size)
```

```
optimizer = tf.keras.optimizers.Adam()
loss_object = tf.keras.losses.SparseCategoricalCrossentropy(
    from_logits=True, reduction='none')

def loss_function(real, pred):
  mask = tf.math.logical_not(tf.math.equal(real, 0))
  loss_ = loss_object(real, pred)

  mask = tf.cast(mask, dtype=loss_.dtype)
  loss_ *= mask

  return tf.reduce_mean(loss_)


checkpoint_path = "./checkpoints/train"
ckpt = tf.train.Checkpoint(encoder=encoder,
                           decoder=decoder,
                           optimizer = optimizer)
ckpt_manager = tf.train.CheckpointManager(ckpt, checkpoint_path, max_to_keep=5)



start_epoch = 0
if ckpt_manager.latest_checkpoint:
  start_epoch = int(ckpt_manager.latest_checkpoint.split('-')[-1])


# adding this in a separate cell because if you run the training cell
# many times, the loss_plot array will be reset
loss_plot = []



@tf.function
def train_step(img_tensor, target):
  loss = 0

                                     r each batch
                                     ated from image to image
                                     _size=target.shape[0])

  dec_input = tf.expand_dims([tokenizer.word_index['']] * BATCH_SIZE, 1)

  with tf.GradientTape() as tape:
      features = encoder(img_tensor)

      for i in range(1, target.shape[1]):
          # passing the features through the decoder
          predictions, hidden, _ = decoder(dec_input, features, hidden)

          loss += loss_function(target[:, i], predictions)

          # using teacher forcing
          dec_input = tf.expand_dims(target[:, i], 1)

  total_loss = (loss / int(target.shape[1]))

  trainable_variables = encoder.trainable_variables + decoder.trainable_variables
```

```
  gradients = tape.gradient(loss, trainable_variables)

  optimizer.apply_gradients(zip(gradients, trainable_variables))

  return loss, total_loss

EPOCHS = 20

for epoch in range(start_epoch, EPOCHS):
    start = time.time()
    total_loss = 0

    for (batch, (img_tensor, target)) in enumerate(dataset):
        batch_loss, t_loss = train_step(img_tensor, target)
        total_loss += t_loss

        if batch % 100 == 0:
            print ('Epoch {} Batch {} Loss {:.4f}'.format(
              epoch + 1, batch, batch_loss.numpy() / int(target.shape[1])))
    # storing the epoch end loss value to plot later
    loss_plot.append(total_loss / num_steps)

    if epoch % 5 == 0:
      ckpt_manager.save()

    print ('Epoch {} Loss {:.6f}'.format(epoch + 1,
                                         total_loss/num_steps))
    print ('Time taken for 1 epoch {} sec\n'.format(time.time() - start))
```

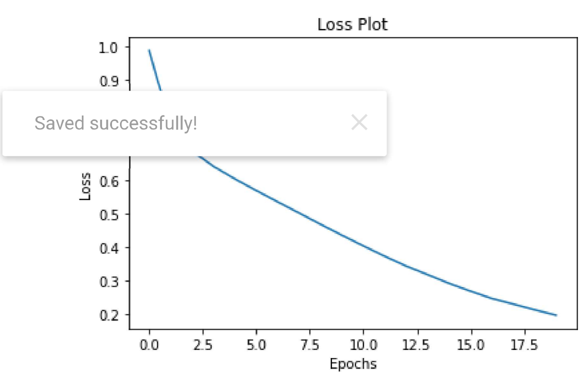
```
Epoch 1 Batch 0 Loss 1.7757
Epoch 1 Batch 100 Loss 1.0993
Epoch 1 Batch 200 Loss 0.9342
Epoch 1 Batch 300 Loss 0.7836
Epoch 1 Loss 0.987433
Time taken for 1 epoch 150.99138712882996 sec
```



```
Epoch 2 Batch 200 Loss 0.7855
Epoch 2 Batch 300 Loss 0.7385
Epoch 2 Loss 0.758385
Time taken for 1 epoch 92.89733481407166 sec

Epoch 3 Batch 0 Loss 0.6938
Epoch 3 Batch 100 Loss 0.7454
Epoch 3 Batch 200 Loss 0.6950
Epoch 3 Batch 300 Loss 0.6771
Epoch 3 Loss 0.688121
Time taken for 1 epoch 93.46923422813416 sec

Epoch 4 Batch 0 Loss 0.6016
Epoch 4 Batch 100 Loss 0.6971
Epoch 4 Batch 200 Loss 0.6294
Epoch 4 Batch 300 Loss 0.6367
Epoch 4 Loss 0.642217
Time taken for 1 epoch 94.37649202346802 sec

Epoch 5 Batch 0 Loss 0.6404
Epoch 5 Batch 100 Loss 0.6506
Epoch 5 Batch 200 Loss 0.5722
```

```
Epoch 5 Batch 300 Loss 0.5898
Epoch 5 Loss 0.604603
Time taken for 1 epoch 95.07147359848022 sec

Epoch 6 Batch 0 Loss 0.6034
Epoch 6 Batch 100 Loss 0.6051
Epoch 6 Batch 200 Loss 0.5710
Epoch 6 Batch 300 Loss 0.5888
Epoch 6 Loss 0.569801
Time taken for 1 epoch 95.76601123809814 sec

Epoch 7 Batch 0 Loss 0.5465
Epoch 7 Batch 100 Loss 0.5867
Epoch 7 Batch 200 Loss 0.5671
Epoch 7 Batch 300 Loss 0.5107
Epoch 7 Loss 0.536289
Time taken for 1 epoch 95.23794054985046 sec

Epoch 8 Batch 0 Loss 0.4975
Epoch 8 Batch 100 Loss 0.5211
Epoch 8 Batch 200 Loss 0.4798
Epoch 8 Batch 300 Loss 0.5148
Epoch 8 Loss 0.503026
Time taken for 1 epoch 92.91645836830139 sec

Epoch 9 Batch 0 Loss 0.4863
Epoch 9 Batch 100 Loss 0.4748
```

```
plt.plot(loss_plot)
plt.xlabel('Epochs')
plt.ylabel('Loss')
plt.title('Loss Plot')
plt.show()
```



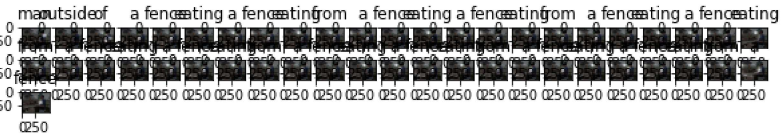

```
def evaluate(image):
    attention_plot = np.zeros((max_length, attention_features_shape))

    hidden = decoder.reset_state(batch_size=1)

    temp_input = tf.expand_dims(load_image(image)[0], 0)
    img_tensor_val = image_features_extract_model(temp_input)
    img_tensor_val = tf.reshape(img_tensor_val, (img_tensor_val.shape[0], -1, img_tensor_val.shape[3]))
```

```
    features = encoder(img_tensor_val)

    dec_input = tf.expand_dims([tokenizer.word_index['']], 0)
    result = []

    for i in range(max_length):
        predictions, hidden, attention_weights = decoder(dec_input, features, hidden)

        attention_plot[i] = tf.reshape(attention_weights, (-1, )).numpy()

        predicted_id = tf.argmax(predictions[0]).numpy()
        result.append(tokenizer.index_word[predicted_id])

        if tokenizer.index_word[predicted_id] == '':
            return result, attention_plot

        dec_input = tf.expand_dims([predicted_id], 0)

    attention_plot = attention_plot[:len(result), :]
    return result, attention_plot


def plot_attention(image, result, attention_plot):
    temp_image = np.array(Image.open(image))

    fig = plt.figure(figsize=(10, 10))

    len_result = len(result)
    for l in range(len_result):
        temp_att = np.resize(attention_plot[l], (8, 8))
        ax = fig.add_subplot(len_result//2, len_result//2, l+1)
        ax.set_title(result[l])
        img = ax.imshow(temp_image)
        ax.imshow(temp_att, cmap='gray', alpha=0.6, extent=img.get_extent())

    plt.tight_layout()
    plt.show()
```



```
# captions on the validation set
rid = np.random.randint(0, len(img_name_val))
image = img_name_val[rid]
real_caption = ' '.join([tokenizer.index_word[i] for i in cap_val[rid] if i not in [0]])
result, attention_plot = evaluate(image)

print ('Real Caption:', real_caption)
print ('Prediction Caption:', ' '.join(result))
plot_attention(image, result, attention_plot)
# opening the image
Image.open(img_name_val[rid])
```

```
Real Caption: a man feeding a giraffe over a wooden fence
Prediction Caption: man outside of a fence eating a fence eating from a fence eating a fence eating fro
<ipython-input-35-18f2724a84a5>:14: UserWarning: Tight layout not applied. tight_layout cannot make axe
  plt.tight_layout()
```



```
image_url = 'https://tensorflow.org/images/surf.jpg'
image_extension = image_url[-4:]
image_path = tf.keras.utils.get_file('image'+image_extension,
                                     origin=image_url)

result, attention_plot = evaluate(image_path)
print ('Prediction Caption:', ' '.join(result))
plot_attention(image_path, result, attention_plot)
# opening the image
Image.open(image_path)
```

```
Prediction Caption: person riding a wave in the water be surfboarding in the water be surfboarding in t
<ipython-input-35-18f2724a84a5>:14: UserWarning: Tight layout not applied. tight_layout cannot make axe
  plt.tight_layout()
```