Pre-Requisites

1.

Visit the link [https://drive.google.com/file/d/1-mPKMpphaKqtT26ZzbR5hCHGedkNyAf1/view?usp=sharing]

Go to drive.google.com

Under 'Shared with me', find the file named **Image_Captioning_Dataset.zip**

Right click -> Add Shortcut to Drive

Select 'My Drive'

Click 'Add Shortcut'

---

2. Visit the link [https://drive.google.com/file/d/1QG2_tAFLroc4ATSOLRiEAwYTYTsL_xVc/view?usp=sharing]

Go to drive.google.com

Under 'Shared with me', find the file named **set_3.pkl**

Right click -> Add Shortcut to Drive

Select 'My Drive'

Click 'Add Shortcut'

Upload a file to gdrive/MyDrive

rename it as: **google-image.jpg**

```
os.environ['TF_CPP_MIN_LOG_LEVEL'] = '2'

import pickle
from google.colab import drive
import re
from nltk.tokenize import RegexpTokenizer
import nltk
from nltk.corpus import stopwords
from nltk.tokenize import word_tokenize
from itertools import islice
from collections import defaultdict
import seaborn as sns
import matplotlib.pyplot as plt
import zipfile
import os

from operator import itemgetter
import matplotlib.pyplot as plt
```

```
import pandas as pd

from keras.preprocessing.image import load_img
from IPython.display import Image, display
import math
from textwrap import wrap

import numpy as np
from keras.applications.vgg16 import VGG16
from keras.utils.vis_utils import plot_model
from tensorflow.keras.utils import to_categorical

from keras.models import Model, load_model
from keras.layers import Input, Dense, Dropout, GRU, Embedding
from keras.preprocessing.text import Tokenizer
from keras.preprocessing.sequence import pad_sequences
from keras.layers.merge import add
from keras.callbacks import ModelCheckpoint, EarlyStopping, ReduceLROnPlateau

from pickle import dump
from keras.preprocessing.image import img_to_array
from keras.applications.vgg16 import preprocess_input
nltk.download('punkt')
```

```
[nltk_data] Downloading package punkt to /root/nltk_data...
[nltk_data]   Unzipping tokenizers/punkt.zip.
True
```

```
drive_path = '/content/gdrive'
drive.mount(drive_path)
```

```
Mounted at /content/gdrive
```

Saved successfully!

```
drive_path)

pickle_path = '{}/set_3.pkl'.format(root_path)

dataset_zip_path = '{}/Image_captioning_Dataset.zip'.format(root_path)
dataset_path = '{}/Flicker8k_Dataset'.format(root_path)

glove_zip_name = 'glove.6B.zip'
glove_zip_path = '{}/{}'.format(root_path, glove_zip_name)
glove_dataset_file = '{}/glove.6B.200d.txt'.format(root_path)


# download and copy/move glove dataset to drive
if not os.path.exists(glove_zip_path):
  print("downloading glove dataset, please wait for some time...")
  !wget 'https://nlp.stanford.edu/data/glove.6B.zip'

  print("uploading glove dataset to drive, this may take a few minutes...")
  !mv {'./' + glove_zip_name}  {glove_zip_path}
  with zipfile.ZipFile(glove_zip_path,"r") as zip_ref:
```

```
    zip_ref.extractall(os.path.dirname(glove_zip_path))
```

```
    downloading glove dataset, please wait for some time...
    --2021-08-08 15:58:46--  https://nlp.stanford.edu/data/glove.6B.zip
    Resolving nlp.stanford.edu (nlp.stanford.edu)... 171.64.67.140
    Connecting to nlp.stanford.edu (nlp.stanford.edu)|171.64.67.140|:443... conne
    HTTP request sent, awaiting response... 301 Moved Permanently
    Location: http://downloads.cs.stanford.edu/nlp/data/glove.6B.zip [following]
    --2021-08-08 15:58:47--  http://downloads.cs.stanford.edu/nlp/data/glove.6B.z
    Resolving downloads.cs.stanford.edu (downloads.cs.stanford.edu)... 171.64.64.
    Connecting to downloads.cs.stanford.edu (downloads.cs.stanford.edu)|171.64.64
    HTTP request sent, awaiting response... 200 OK
    Length: 862182613 (822M) [application/zip]
    Saving to: ‘glove.6B.zip’

    glove.6B.zip        100%[===================>] 822.24M  5.02MB/s    in 2m 40s

    2021-08-08 16:01:26 (5.14 MB/s) - ‘glove.6B.zip’ saved [862182613/862182613]

    uploading glove dataset to drive, this may take a few minutes...
```

```
# extract the dataset
if not os.path.exists(dataset_path):
  print("extracting image_captioning dataset, this may take a couple of minutes...'
  with zipfile.ZipFile(dataset_zip_path,"r") as zip_ref:
      zip_ref.extractall(os.path.dirname(dataset_zip_path))
else:
  print("dataset extracted already!")
```

```
    extracting image_captioning dataset, this may take a couple of minutes...
```

```
# read the pickle dataset
objects = []
with open(pickle_path, "rb") as openfile:
    while True:
        try:
            objects.append(pickle.load(openfile))
        except EOFError:
            break
print(len(objects))
objects[0][:10]
```

Saved successfully!

```
    1
    ['3033668641_5905f73990.jpg#0\tA man in a white helmet cling to a sheer rock
     '2608289957_044849f73e.jpg#0\tA baby sit on a tire and hold a toy .',
     '2723477522_d89f5ac62b.jpg#4\ttwo dog play in the grass .',
     '3453019315_cfd5c10dae.jpg#2\tA man do a bike trick on a dirt path .',
     '3524975665_7bec41578b.jpg#1\tA woman in a yellow jacket and brown hat stand
     '3461041826_0e24cdf597.jpg#2\tA black and white dog be splash in a stream .'
     '414568315_5adcfc23c0.jpg#4\tA child be use chopstick on overturned kitchen
     '2657484284_daa07a3a1b.jpg#0\tA kayak on a river be pass by a wire bridge th
     '2860667542_95abec3380.jpg#2\tA white water bird take flight from a lake .',
     '2222498879_9e82a100ab.jpg#3\tA tan and black dog walk happy through a field
```

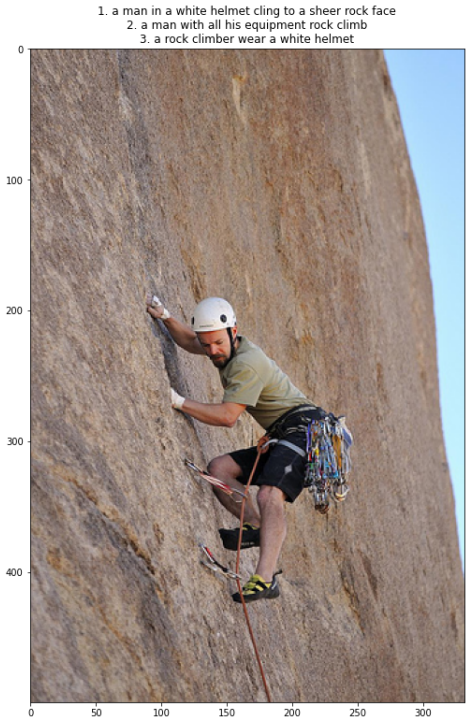
```
# convert to required format, remove punctuations, lowercase the captions.

captions_dict = defaultdict(list)
tokenizer = RegexpTokenizer(r'\w+')

for record in objects[0]:
  (name, caption_num, caption) = re.split(r'#|\t', record, maxsplit=2)

  # do not add it to captions_dict (or training/testing sets if we don't have a fil
  if not os.path.exists(os.path.join(dataset_path, name)):
    continue

  # remove stopwords, convert to lowercase, remove punctuations.
  caption_words = tokenizer.tokenize(caption.lower())
  captions_dict[name].append(' '.join(caption_words))

dict(islice(captions_dict.items(), 5))
```

```
{'2608289957_044849f73e.jpg': ['a baby sit on a tire and hold a toy',
  'boy in pajama with red and yellow toy seat on tire near plant',
  'a little kid with a red toy be sit on a tire',
  'child hold plastic car sit on a tire'],
 '2723477522_d89f5ac62b.jpg': ['two dog play in the grass',
  'a large brown dog be chase after a little brown dog',
  'a big dog chase a little dog on the grass',
  'two brown dog run through the grass together'],
 '3033668641_5905f73990.jpg': ['a man in a white helmet cling to a sheer rock
  'a man with all his equipment rock climb',
  'a rock climber wear a white helmet'],
 '3453019315_cfd5c10dae.jpg': ['a man do a bike trick on a dirt path',
  'man perform a trick on a bicycle outside',
  'a helmeted male airborne on a bike on a dirt road'],
 '3524975665_7bec41578b.jpg': ['a woman in a yellow jacket and brown hat stan
  'a young woman wait under a sculpture in a park',
  'a woman in a yellow coat be stand on a sidewalk']}
```

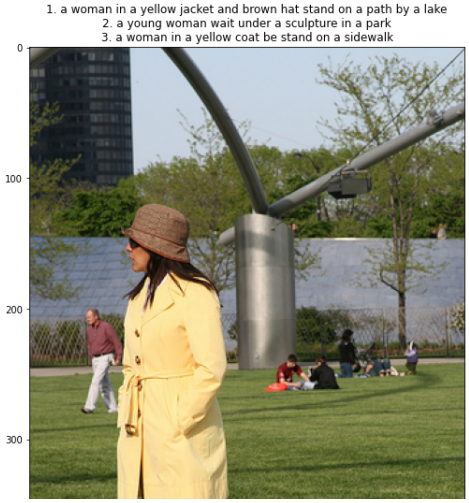
Saved successfully!

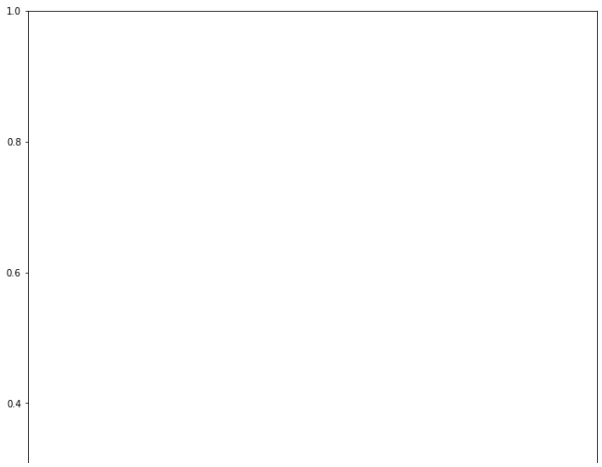
```
# display N sample images and their captions.


def display_images(dataset_path, filenames, captions_dict, title=True):

  N = len(filenames)
  ncols = 2   # number of columns in the grid

  # create a grid.
  fig, axes = plt.subplots(nrows=math.ceil(N/ncols), ncols=ncols, figsize=(24,24),

  # adjust grid spacing to accomodate multiple captions.
  fig.subplots_adjust(left=None, bottom=None, right=None, top=1.5, wspace=None, hsp


  count = 0
  for filename in filenames:
    (i, j) = (count // ncols, count % ncols)    # grid i, j coordinates
```

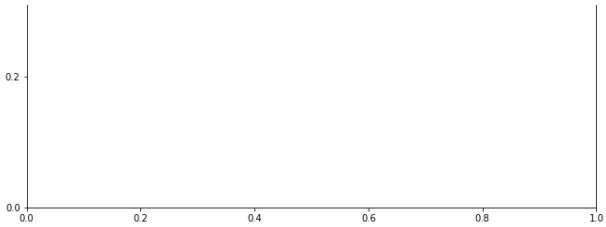
```
        image = load_img(os.path.join(dataset_path, filename))
        axes[i, j].imshow(image)

        # number the title, wrap long titles (to default 70 char width)
        if title:
          title = "\n".join(["{}. {}".format(i+1, "\n".join(wrap(v))) for i, v in enume
          axes[i, j].title.set_text(title)

        count += 1
        if count >= N:
          break


display_images(dataset_path, list(captions_dict.keys())[:5], captions_dict)
```



Saved successfully!








```
# split captions data in training/test sets

train_ratio = 0.9

image_names = [x for x in captions_dict.keys()]

# NOTE:
# with shuffle = False, The code shall extract image features on the first run, and
# save it to disk for training and testing datasets, subsequent runs shall re-use t
#
# shuffle=True will re-extract training/test image features every time and will NOT
# save it do disk.
shuffle = False
if shuffle:
  np.random.shuffle(image_names)

train_size = int(len(image_names) * train_ratio)

train_data = dict({k: captions_dict[k] for k in image_names[:train_size]})
test_data = dict({k: captions_dict[k] for k in image_names[train_size:]})

print("sample captions from training dataset\n------------------")
print(dict(islice(train_data.items(), 5)), "\n\n")
                                          ing dataset\n------------------")
                                          s(), 5)), "\n\n")
print('size - training dataset: {}, testing dataset: {}'.format(len(train_data), len(test
```

Saved successfully!

```
sample captions from training dataset
------------------
{'3033668641_5905f73990.jpg': ['a man in a white helmet cling to a sheer rock


sample captions from testing dataset
------------------
{'3471841031_a949645ba8.jpg': ['people at park sit on bench and a woman take (


'size - training dataset: 7214, testing dataset: 802'
```

```
# update training and test data captions with BOS/EOS markers
for key, captions in train_data.items():
  new_captions = ['startseq {} endseq'.format(caption) for caption in captions]
  train_data[key] = new_captions
```

```
for key, captions in test_data.items():
  new_captions = ['startseq {} endseq'.format(caption) for caption in captions]
  test_data[key] = new_captions

print("sample captions from training dataset\n-------------------")
print(dict(islice(train_data.items(), 5)), "\n\n")
print("sample captions from testing dataset\n-------------------")
print(dict(islice(test_data.items(), 5)), "\n\n")
'size - training dataset: {}, testing dataset: {}'.format(len(train_data), len(test
```

```
sample captions from training dataset
-------------------
{'3033668641_5905f73990.jpg': ['startseq a man in a white helmet cling to a s


sample captions from testing dataset
-------------------
{'3471841031_a949645ba8.jpg': ['startseq people at park sit on bench and a wo


'size - training dataset: 7214, testing dataset: 802'
```

```
# create a word count dictionary.

vocabulary = set()
word_count = defaultdict(lambda: 0)
for captions in train_data.values():
  for caption in captions:
    for word in str.split(caption, ' '):
      vocabulary.add(word)
      if word not in ['startseq', 'endseq']:
        word_count[word] += 1

                                    lues.
                                    unt.items(), key = itemgetter(1), reverse = True))
```

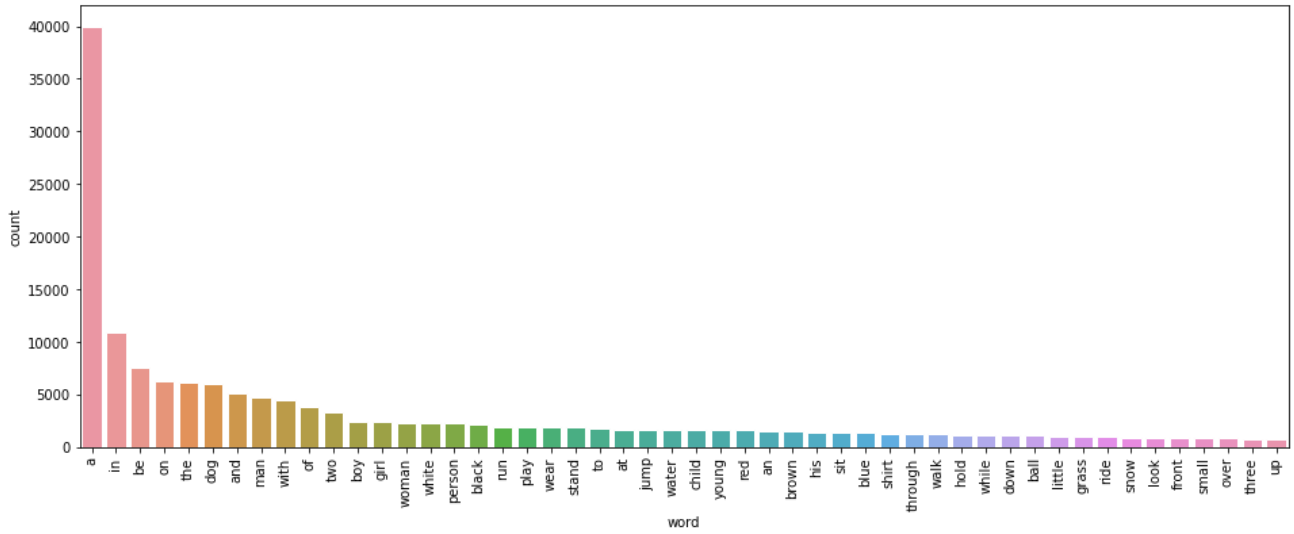


```
# total vocab size
print(len(vocabulary))
```

```
5142
```

```
# plot top 50 words from word_count dict.
plt.figure(figsize=(16,6))
plt.xticks(rotation='vertical')

df = pd.DataFrame(word_count.items(), columns=['word', 'count'])
sns.set(style="whitegrid")
sns.barplot(x='word', y='count', data=df[:50])
```

```
<matplotlib.axes._subplots.AxesSubplot at 0x7f0258a16dd0>
```

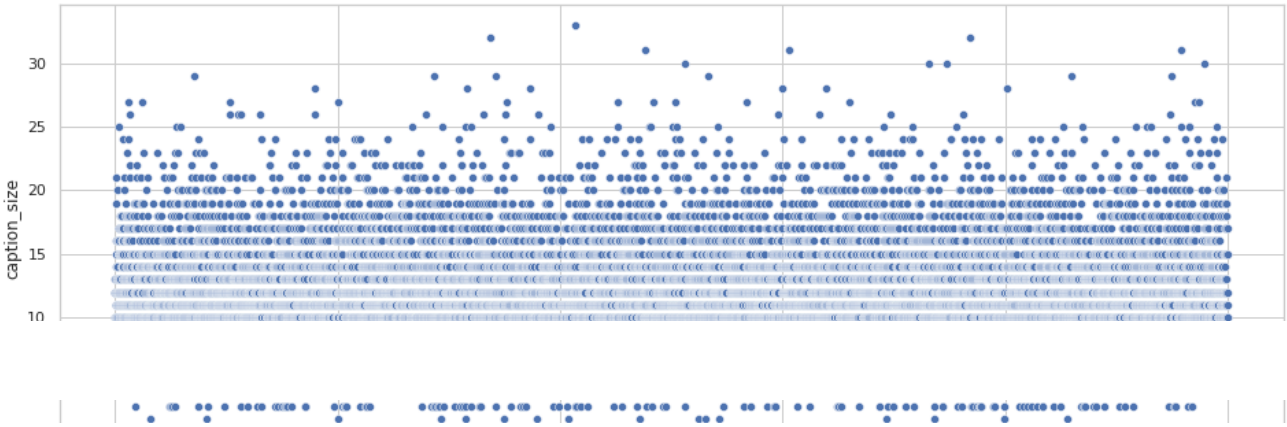



```
# caption words (min, max, avg.)

caption_sizes = {}
i=0
for captions in captions_dict.values():
  for caption in captions:
    caption_sizes[i] = len(str.split(caption, ' '))
    i += 1

df1 = pd.DataFrame(caption_sizes.items(), columns=['index', 'caption_size'])
```

Saved successfully!

```
sns.set(style="whitegrid")
sns.scatterplot(x='index', y='caption_size', data=df1)
df1['caption_size'].describe()
```

```
count    24995.000000
mean        10.775155
std          3.773125
min          1.000000
25%          8.000000
50%         10.000000
75%         13.000000
max         33.000000
Name: caption_size, dtype: float64
```

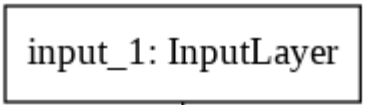


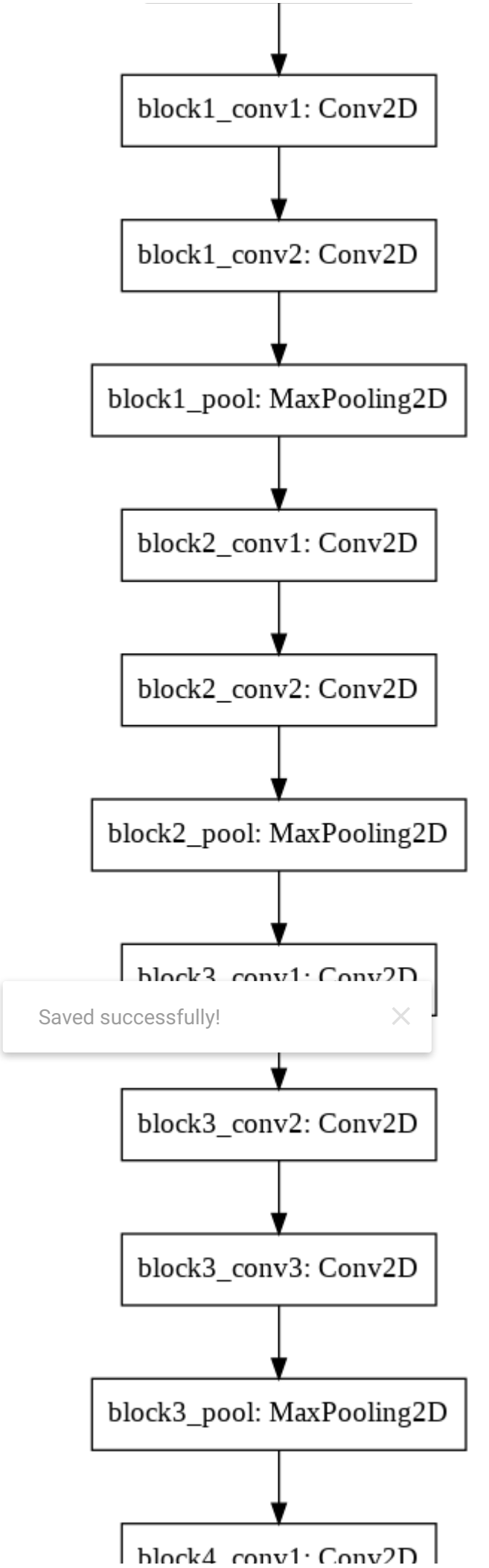

```
# use the VGG16 pretrained model to extract features from images.
model = VGG16(weights='imagenet')
print(model.summary())
plot_model(model, to_file='{}/vgg.png'.format(root_path))
```

Saved successfully!

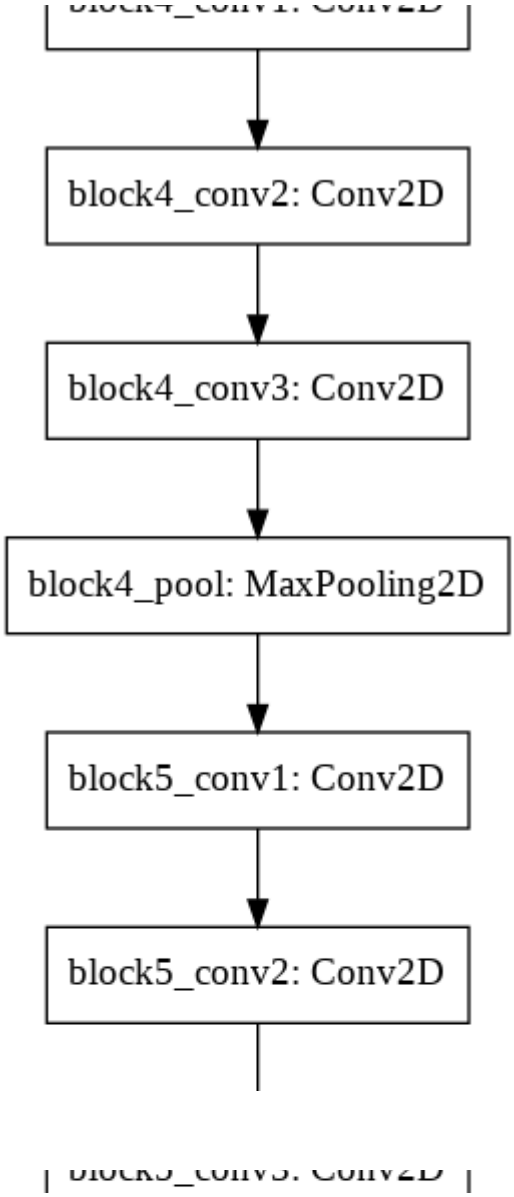
```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applica
553467904/553467096 [==============================] - 4s 0us/step
553476096/553467096 [==============================] - 4s 0us/step
Model: "vgg16"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 224, 224, 3)]     0
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 224, 224, 64)      1792
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 224, 224, 64)      36928
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 112, 112, 64)      0
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 112, 112, 128)     73856
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 112, 112, 128)     147584
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 56, 56, 128)       0
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 56, 56, 256)       295168
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 28, 28, 256)       0
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 28, 28, 512)       1180160
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 14, 14, 512)       0
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv3 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_pool (MaxPooling2D)   (None, 7, 7, 512)         0
_________________________________________________________________
flatten (Flatten)            (None, 25088)             0
_________________________________________________________________
fc1 (Dense)                  (None, 4096)              102764544
_________________________________________________________________
fc2 (Dense)                  (None, 4096)              16781312
_________________________________________________________________
predictions (Dense)          (None, 1000)              4097000
=================================================================
Total params: 138,357,544
Trainable params: 138,357,544
Non-trainable params: 0
_________________________________________________________________
None
```

Saved successfully!





Saved successfully!



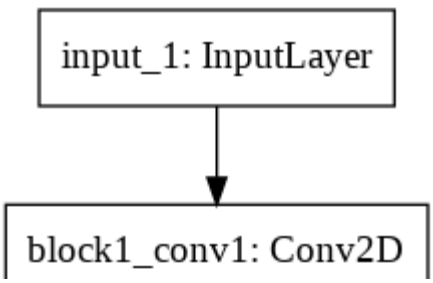

```
# recreate model removing last prediction layer
model1 = Model(inputs=model.inputs, outputs=model.layers[-2].output)
print(model1.summary())
```

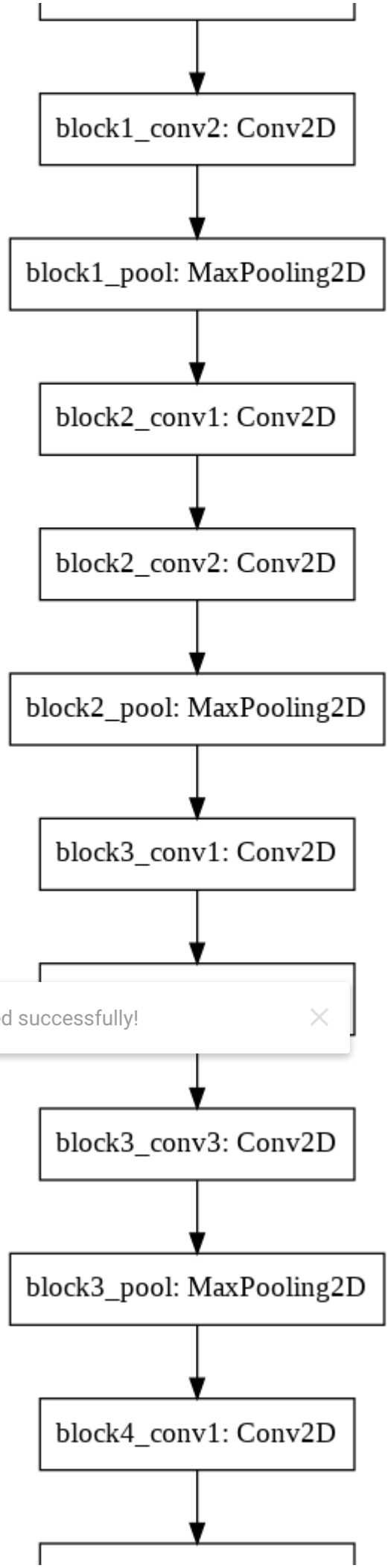
```
gg-1.png'.format(root_path))
```

Saved successfully!

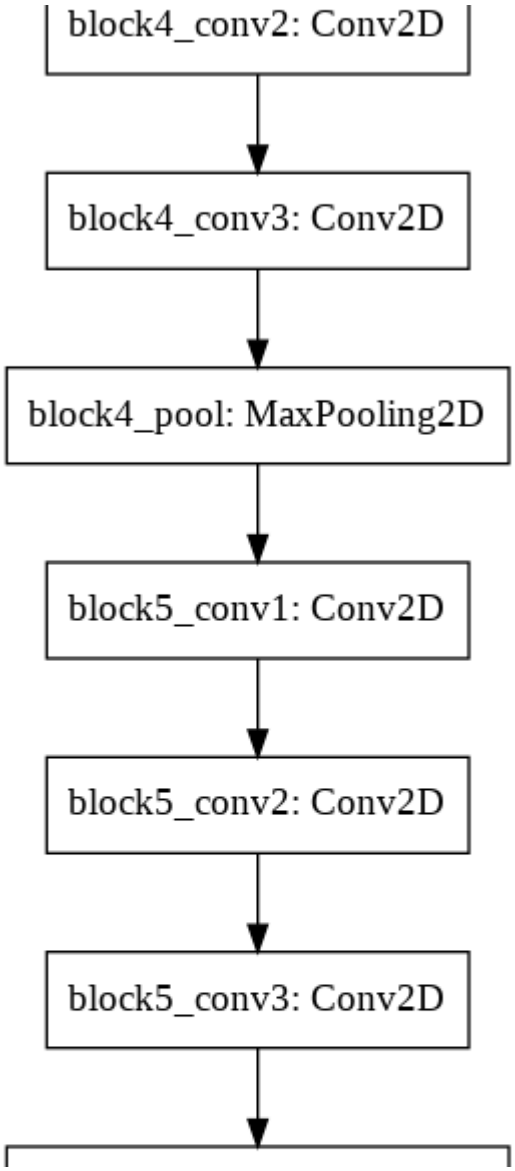
```
Model: "model"
_________________________________________________________________
Layer (type)                 Output Shape              Param #
=================================================================
input_1 (InputLayer)         [(None, 224, 224, 3)]     0
_________________________________________________________________
block1_conv1 (Conv2D)        (None, 224, 224, 64)      1792
_________________________________________________________________
block1_conv2 (Conv2D)        (None, 224, 224, 64)      36928
_________________________________________________________________
block1_pool (MaxPooling2D)   (None, 112, 112, 64)      0
_________________________________________________________________
block2_conv1 (Conv2D)        (None, 112, 112, 128)     73856
_________________________________________________________________
block2_conv2 (Conv2D)        (None, 112, 112, 128)     147584
_________________________________________________________________
block2_pool (MaxPooling2D)   (None, 56, 56, 128)       0
_________________________________________________________________
block3_conv1 (Conv2D)        (None, 56, 56, 256)       295168
_________________________________________________________________
block3_conv2 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_conv3 (Conv2D)        (None, 56, 56, 256)       590080
_________________________________________________________________
block3_pool (MaxPooling2D)   (None, 28, 28, 256)       0
_________________________________________________________________
block4_conv1 (Conv2D)        (None, 28, 28, 512)       1180160
_________________________________________________________________
block4_conv2 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_conv3 (Conv2D)        (None, 28, 28, 512)       2359808
_________________________________________________________________
block4_pool (MaxPooling2D)   (None, 14, 14, 512)       0
_________________________________________________________________
block5_conv1 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
block5_conv2 (Conv2D)        (None, 14, 14, 512)       2359808
_________________________________________________________________
                             (None, 14, 14, 512)       2359808
_________________________________________________________________
                             (None, 7, 7, 512)         0
_________________________________________________________________
flatten (Flatten)            (None, 25088)             0
_________________________________________________________________
fc1 (Dense)                  (None, 4096)              102764544
_________________________________________________________________
fc2 (Dense)                  (None, 4096)              16781312
=================================================================
Total params: 134,260,544
Trainable params: 134,260,544
Non-trainable params: 0
_________________________________________________________________
None
```

Saved successfully!





Saved successfully!



The model above takes images as **224 x 224 x 3** size.

Saved successfully!

```
# use above model to extract features from images.
def extract_image_features(model, data, dataset_path):
  image_features = dict()
  for filename in data.keys():

    filepath = os.path.join(dataset_path, filename)
    if not os.path.exists(filepath):
      continue

    image = load_img(filepath, target_size=(224, 224))

    # reshape the image
    image = img_to_array(image)
    image = expand_dims(image, axis=0)

    # preprocess
    image = preprocess_input(image)
```

```
    # extract features
    image_features[filename] = model1.predict(image, verbose=0)

  return image_features


train_data_dump_path = '{}/image_features_train-set.pkl'.format(root_path)
test_data_dump_path = '{}/image_features_test-set.pkl'.format(root_path)

if shuffle or not os.path.exists(train_data_dump_path):
  print("extracting image features from training data.. please wait for 5-10 minute
  image_features_train = extract_image_features(model, train_data, dataset_path)

  # No point in saving shuffled image features to disk, as next suffle won't have
  # the same set of images in training or test dataset.
  if not shuffle:
    with open(train_data_dump_path, "wb") as fh:
      dump(image_features_train, fh)

if shuffle or not os.path.exists(test_data_dump_path):
  print("extracting image features from test data.. please wait for 2-3 minutes.")

  image_features_test = extract_image_features(model, test_data, dataset_path)
  # No point in saving shuffled image features to disk, as next suffle won't have
  # the same set of images in training or test dataset.
  if not shuffle:
    with open(test_data_dump_path, "wb") as fh:
      dump(image_features_test, fh)
```

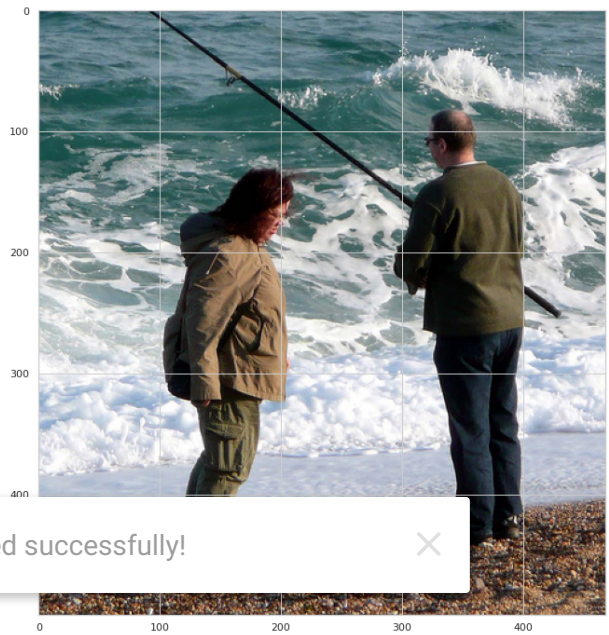
```
    extracting image features from training data.. please wait for 5-10 minutes.
    extracting image features from test data.. please wait for 2-3 minutes.
```

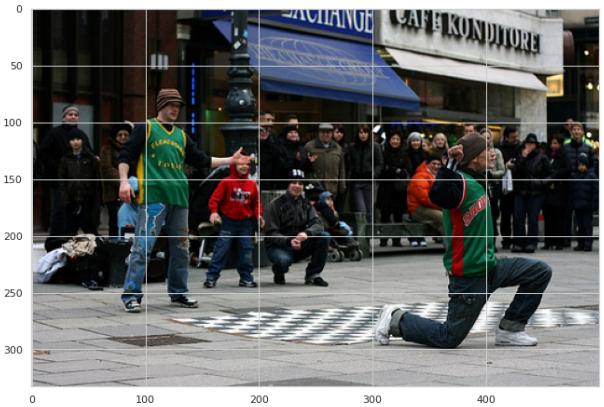
```
# load image features from test dump file, display samples.

  print("loading training image features from pickle file")
  with open(test_data_dump_path, "rb") as fh:
  image_features_test = pickle.load(fh)

print('feature set size: {}'.format(len(image_features_test)))

# print 5 items
dict(islice(image_features_test.items(), 5))
```



```
    loading training image features from pickle file
    feature set size: 802
    {'1499495021_d295ce577c.jpg': array([[0.42266178, 0.        , 0.06778109, ...
            0.886196  ]], dtype=float32),
     '2167644298_100ca79f54.jpg': array([[1.9898707, 1.854141 , 0.       , ..., 0
            2.3647237]], dtype=float32),
     '3228517564_74b00a923b.jpg': array([[0.        , 0.        , 0.        , ...
            2.6010358 ]], dtype=float32),
     '3259992638_0612a40288.jpg': array([[0.       , 0.       , 0.       , ..., 0
            0.5030978]], dtype=float32),
```

```
        '3471841031_a949645ba8.jpg': array([[1.4077761, 1.5905311, 1.8254167, ..., 0
                0.       ]], dtype=float32)}


    # display some test data, before generating captions for it.

    display_images(dataset_path, list(test_data.keys())[:5], test_data, title=False)
```





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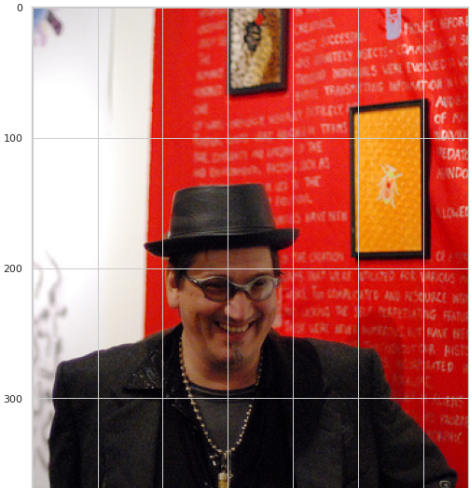

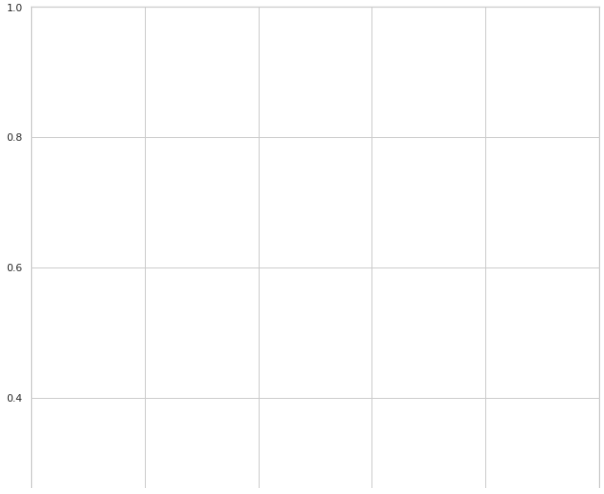

```
# also display extaracted features for the above images.
def display_features(filename, layer=1):

  features = 64
  ncols = 8   # number of columns in the grid
  nrows = features//ncols

  layer_op = Model(inputs=model.inputs, outputs=model.layers[layer].output)

  # create a grid.
  fig, axes = plt.subplots(nrows=nrows, ncols=ncols, figsize=(8,8), squeeze=False)

  image = load_img(os.path.join(dataset_path, filename), target_size=(224, 224))
  image = img_to_array(image)
  image = expand_dims(image, axis=0)
  image = preprocess_input(image)

  feature_map = layer_op.predict(image)
  for fmap in feature_map:
    count = 0
    for r in range(nrows):
      for c in range(ncols):
        axes[r, c].set_xticks([])
        axes[r, c].set_yticks([])
        axes[r, c].imshow(fmap[ :, :, count], cmap='gray')
        count += 1


# displaying features (produced at layer 1) from the biker photo above (index 1).
photo_index = 1
display_features(list(test_data.keys())[photo_index], layer=1)
```

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Let's generate captions for the images above.

```
# interpret the output of prediction layer.
from keras.applications.vgg16 import decode_predictions

img_name = list(test_data.keys())[photo_index]
image = load_img(os.path.join(dataset_path, img_name), target_size=(224, 224))
image = img_to_array(image)
image = image.reshape((1, image.shape[0], image.shape[1], image.shape[2]))
image = preprocess_input(image)
yhat = model.predict(image)
label = decode_predictions(yhat)
print(label)
```

```
Downloading data from https://storage.googleapis.com/download.tensorflow.org/
40960/35363 [================================] - 0s 0us/step
49152/35363 [==========================================] - 0s 0us/step
[[('n03792782', 'mountain_bike', 0.7762148), ('n04509417', 'unicycle', 0.1126
```

```
# create a word count dictionary.
word_count = defaultdict(lambda: 0)
for word in caption_words:
  word_count[word] += 1

vocab_len = len(vocabulary) + 1   # add 1 for padding.

max_caption_len = df1['caption_size'].max()
"vocabulary length: {}, max caption length: {}".format(vocab_len, max_caption_len)
```

Saved successfully!

```
'ax caption length: 33'
```

```
# using tokenizer for word <-> index mappings.
from keras.preprocessing.text import Tokenizer as KerasTokenizer
tokenizer = KerasTokenizer(num_words=vocab_len)
tokenizer.fit_on_texts(vocabulary)

print(tokenizer.word_index)
print(tokenizer.index_word)
```

```
{'sombrero': 1, 'hairclips': 2, 'three': 3, 'itself': 4, 'properly': 5, 'slee
{1: 'sombrero', 2: 'hairclips', 3: 'three', 4: 'itself', 5: 'properly', 6: 's
```

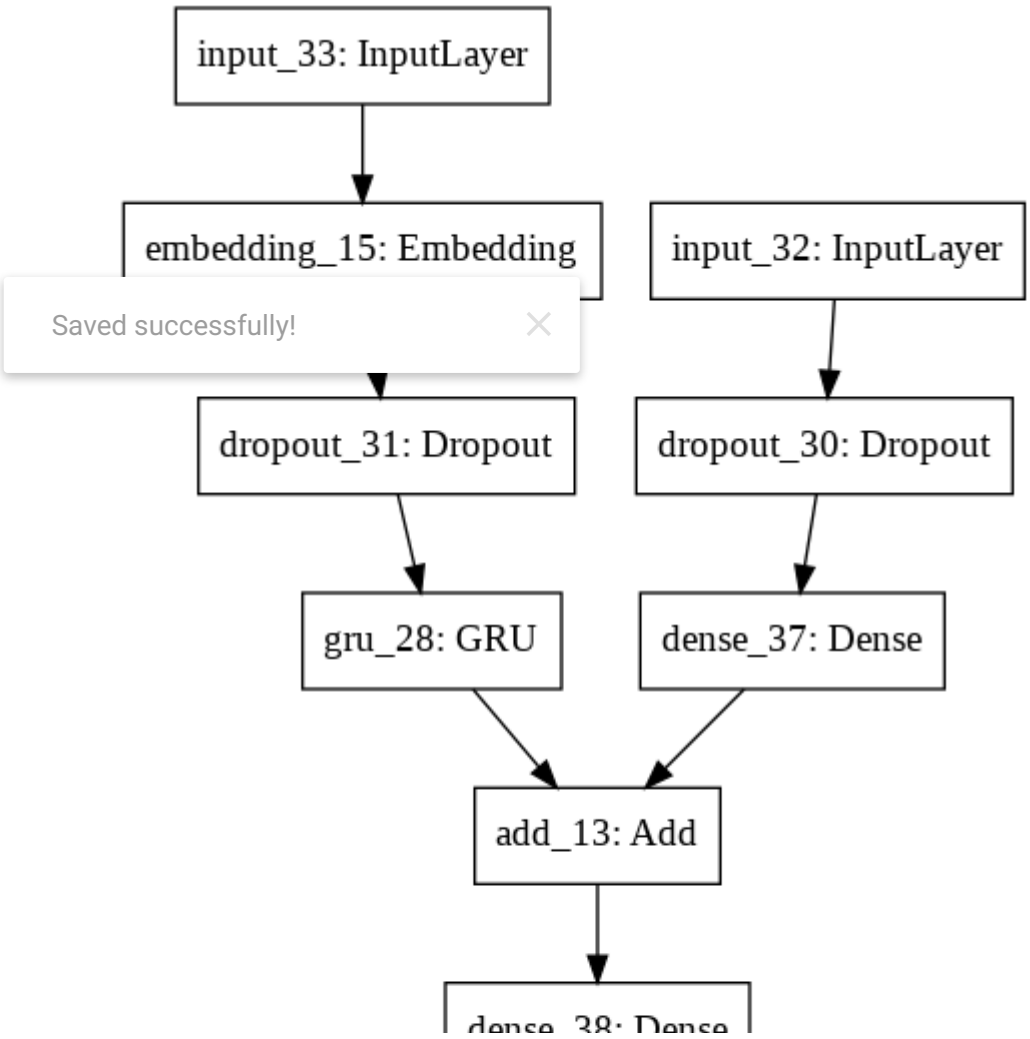
```
# Load Glove vectors
embeddings_index = {} # empty dictionary
with open(glove_dataset_file, "r", encoding="utf-8") as fh:
  for line in fh:
    values = line.split()
```

```
        word = values[0]
        coefs = np.asarray(values[1:], dtype='float32')
        embeddings_index[word] = coefs

    embedding_dim = 200
    # Get 200-dim dense vector for each of the words in out vocabulary
    embedding_matrix = np.zeros((vocab_len, embedding_dim))
    for word, i in tokenizer.word_index.items():
        embedding_vector = embeddings_index.get(word)
        if embedding_vector is not None:
            # Words not found in the embedding index will be all zeros
            embedding_matrix[i] = embedding_vector



    from tensorflow.keras import regularizers
    from tensorflow.keras.optimizers import Adam

    # image feature extractor model
    inputs1 = Input(shape=(4096,))
    fe1 = Dropout(0.3)(inputs1)
    fe2 = Dense(256, activation='relu')(fe1)

    # partial caption sequence model
    inputs2 = Input(shape=(max_caption_len,))
    se1 = Embedding(vocab_len, output_dim=200,  mask_zero=True)(inputs2)
    se2 = Dropout(0.3)(se1)
    # stacking multiple GRU layers
    se3 = GRU(256, kernel_regularizer=regularizers.l2(0.01))(se2)

    # decoder (feed forward) model
    decoder1 = add([fe2, se3])
    decoder2 = Dense(256, activation='relu')(decoder1)
    outputs = Dense(vocab_len, activation='softmax')(decoder2)

    Saved successfully!                                    inputs2], outputs=outputs)
    print(model2.layers)

    model2.layers[2].set_weights([embedding_matrix])
    model2.layers[2].trainable = False
    optimizer = Adam(learning_rate=0.001)

    model2.compile(loss='categorical_crossentropy', optimizer=optimizer)
    model2.summary()
    plot_model(model2)
```

```
[<keras.engine.input_layer.InputLayer object at 0x7effd8acb550>, <keras.engin
Model: "model_13"
```

Layer (type)	Output Shape	Param #	Connected to
input_33 (InputLayer)	[(None, 33)]	0	
input_32 (InputLayer)	[(None, 4096)]	0	
embedding_15 (Embedding)	(None, 33, 200)	1028600	input_33[0][
dropout_30 (Dropout)	(None, 4096)	0	input_32[0][
dropout_31 (Dropout)	(None, 33, 200)	0	embedding_15
dense_37 (Dense)	(None, 256)	1048832	dropout_30[0
gru_28 (GRU)	(None, 256)	351744	dropout_31[0
add_13 (Add)	(None, 256)	0	dense_37[0][gru_28[0][0]
dense_38 (Dense)	(None, 256)	65792	add_13[0][0]
dense_39 (Dense)	(None, 5143)	1321751	dense_38[0][

```
Total params: 3,816,719
Trainable params: 2,788,119
Non-trainable params: 1,028,600
```



```
def data_gen(captions, features, word_index, max_caption_len, vocab_len, num_photos
  X1, X2, y = list(), list(), list()
  # word_index = tokenizer.word_index
  n=0
  # loop for ever over images
  while 1:
    for key, desc_list in captions.items():
      n+=1
      # retrieve the photo feature
      photo = features[key]
      for desc in desc_list:
        # encode the sequence
        seq = [word_index[word] for word in desc.split(' ') if word in word_index]
        # split one sequence into multiple X, y pairs
        for i in range(1, len(seq)):
          # split into input and output pair
          in_seq, out_seq = seq[:i], seq[i]
          # pad input sequence
          in_seq = pad_sequences([in_seq], maxlen=max_caption_len)[0]
          # encode output sequence
          out_seq = to_categorical([out_seq], num_classes=vocab_len)[0]
          # store
          X1.append(photo[0])
          X2.append(in_seq)
          y.append(out_seq)
      # yield the batch data
      if n==num_photos_per_batch:
        yield [np.array(X1), np.array(X2)], np.array(y) # [[np.array(X1), np.array(
        X1, X2, y = list(), list(), list()
        n=0


# train the model
import tensorflow as tf
tf.config.run_functions_eagerly(True)

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atures from pickle file")
with open(train_data_dump_path, "rb") as fh:
  image_features_train = pickle.load(fh)



epochs = 5
batch_size = 64
steps = len(train_data) // batch_size

model_save_dir = '{}/group-193'.format(root_path)
os.makedirs(model_save_dir, exist_ok=True)

histories = []
for i in range(epochs):
  print('epoch {} of {}'.format(i+1, epochs))
  gen = data_gen(train_data, image_features_train, tokenizer.word_index, max_captio
  history = model2.fit(gen, epochs=1, steps_per_epoch=steps, batch_size=batch_size,
  model2.save('{}/model.{}'.format(model_save_dir, i))
```

```
    histories.append(history)

# load the last saved model results.
recent_model_path = '{}/model.{}'.format(model_save_dir, epochs-1)
recent_model = load_model(recent_model_path)
```

```
loading training image features from pickle file
epoch 1 of 5
/usr/local/lib/python3.7/dist-packages/tensorflow/python/data/ops/dataset_ops
  "Even though the `tf.config.experimental_run_functions_eagerly` "
WARNING:absl:Found untraced functions such as gru_cell_29_layer_call_and_retu
/usr/local/lib/python3.7/dist-packages/keras/utils/generic_utils.py:497: Custo
  category=CustomMaskWarning)
INFO:tensorflow:Assets written to: /content/gdrive/MyDrive/group-193/model.0/a
INFO:tensorflow:Assets written to: /content/gdrive/MyDrive/group-193/model.0/a
epoch 2 of 5
/usr/local/lib/python3.7/dist-packages/tensorflow/python/data/ops/dataset_ops
  "Even though the `tf.config.experimental_run_functions_eagerly` "
WARNING:absl:Found untraced functions such as gru_cell_29_layer_call_and_retu
/usr/local/lib/python3.7/dist-packages/keras/utils/generic_utils.py:497: Custo
  category=CustomMaskWarning)
INFO:tensorflow:Assets written to: /content/gdrive/MyDrive/group-193/model.1/a
INFO:tensorflow:Assets written to: /content/gdrive/MyDrive/group-193/model.1/a
epoch 3 of 5
/usr/local/lib/python3.7/dist-packages/tensorflow/python/data/ops/dataset_ops
  "Even though the `tf.config.experimental_run_functions_eagerly` "
WARNING:absl:Found untraced functions such as gru_cell_29_layer_call_and_retu
/usr/local/lib/python3.7/dist-packages/keras/utils/generic_utils.py:497: Custo
  category=CustomMaskWarning)
INFO:tensorflow:Assets written to: /content/gdrive/MyDrive/group-193/model.2/a
INFO:tensorflow:Assets written to: /content/gdrive/MyDrive/group-193/model.2/a
epoch 4 of 5
/usr/local/lib/python3.7/dist-packages/tensorflow/python/data/ops/dataset_ops
  "Even though the `tf.config.experimental_run_functions_eagerly` "
WARNING:absl:Found untraced functions such as gru_cell_29_layer_call_and_retu
/usr/local/lib/python3.7/dist-packages/keras/utils/generic_utils.py:497: Custo
                                                    )
                                                    en to: /content/gdrive/MyDrive/group-193/model.3/a
                                                    en to: /content/gdrive/MyDrive/group-193/model.3/a
epoch 5 of 5
/usr/local/lib/python3.7/dist-packages/tensorflow/python/data/ops/dataset_ops
  "Even though the `tf.config.experimental_run_functions_eagerly` "
WARNING:absl:Found untraced functions such as gru_cell_29_layer_call_and_retu
/usr/local/lib/python3.7/dist-packages/keras/utils/generic_utils.py:497: Custo
  category=CustomMaskWarning)
INFO:tensorflow:Assets written to: /content/gdrive/MyDrive/group-193/model.4/a
INFO:tensorflow:Assets written to: /content/gdrive/MyDrive/group-193/model.4/a
```



```
from tensorflow.keras.models import load_model

# generate captions.
def greedySearch(rnn_model, photo):
  in_text = 'startseq'
  for i in range(max_caption_len):
    sequence = tokenizer.texts_to_sequences([in_text])[0]
    sequence = pad_sequences([sequence], maxlen=max_caption_len, padding='post')
```

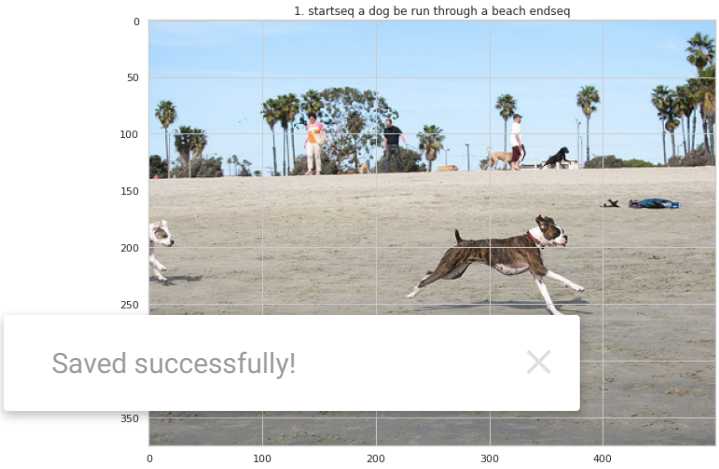
```
        yhat = rnn_model.predict([photo,sequence], verbose=0)
        yhat = np.argmax(yhat)
        word = None
        if tokenizer.index_word.get(yhat):
          word = tokenizer.index_word[yhat]
          in_text += ' ' + word
        else:
          break
        if word == 'endseq':
          break
      return in_text

    index = 101
    key = list(image_features_test.keys())[index]
    value = image_features_test[key]

    label = greedySearch(recent_model, value)
    print(key, label)
    display_images(dataset_path, [key], {key: [label]}, title=True)
```

Saved successfully!

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/data/ops/dataset_ops
  "Even though the `tf.config.experimental_run_functions_eagerly` "
396763804_3b7f1e12a8.jpg startseq a dog be run through a beach endseq
```



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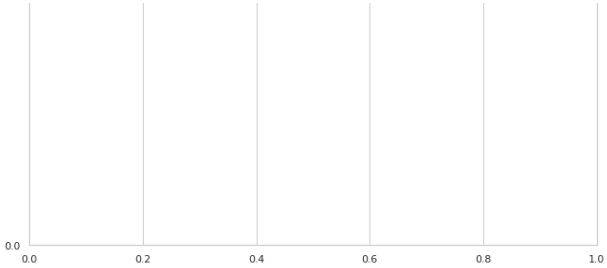
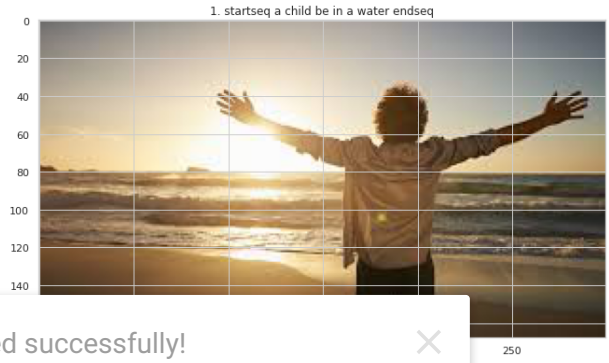



```
# load an image from google

google_image_name = 'google-image.jpg'
google_image_path = '{}/{}'.format(root_path, google_image_name)

if os.path.exists(google_image_path):
  image = load_img(google_image_path, target_size=(224, 224))
  image = img_to_array(image)
  image = image.reshape((1, image.shape[0], image.shape[1], image.shape[2]))
  image = preprocess_input(image)

  # use model-1 here (to produce 4096 feature vector)
  img_feat = model1.predict(image)

  label = greedySearch(recent_model, img_feat)

  display_images(root_path, [google_image_name], {google_image_name: [label]}, titl
```

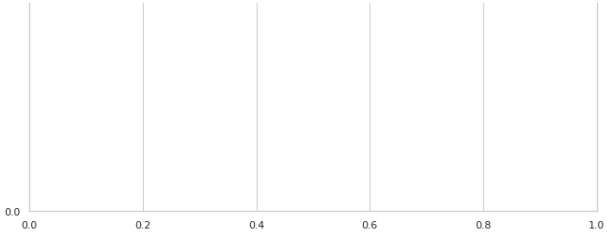
Saved successfully!

```
                                                  t(google_image_path))
```

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/data/ops/dataset_ops
  "Even though the `tf.config.experimental_run_functions_eagerly` "
```



Saved successfully!




```
# evaluation metrics.
```

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```
  print('loss after epoch {} : {}'.format(i, history.history['loss']))
```

```
    loss after epoch 0 : [5.658534526824951]
    loss after epoch 1 : [3.89988374710083]
    loss after epoch 2 : [3.551647186279297]
    loss after epoch 3 : [3.340989828109741]
    loss after epoch 4 : [3.1821258068084717]
```

Notes

We picked adam as the optimizer following a detailed analysis over here:

https://ruder.io/optimizing-gradient-descent/

While not always the best, adaptive learning algorithms may be more suited for sparse data, and work well with lesser memory requirements.

Both vanilla sgd and adam may be used here.

A learning rate of 0.001 was used for Adam optimizer, though various sources differ on an optimal value, many of them ranging from 1e-4 to 0.01, other on the higher side.

Due to time constraints we were not able to experiment with the learning rate and its optmial values, and went ahead with a typical learning rate of 0.001

A batch size of 64 was chosen, we tried with higher number but ran into memory issues, a lower batch size would result in a slower and may be inaccurate results.

Due to time constraints, we could not try with more than 3 epochs. Though the loss seems to be reducing with each epoch, a BLEU score would be more suitable to assess the accuracy of the generated captions.

Double-click (or enter) to edit

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✓ 0s completed at 22:45