```
import os
import warnings
warnings.filterwarnings('ignore')
import numpy as np
import matplotlib.pyplot as plt
import pandas as pd
import seaborn as sns
import plotly.graph_objects as go
import re
import tensorflow as tf
from tensorflow.keras.applications.inception_v3 import InceptionV3
from tensorflow.keras.preprocessing.image import img_to_array, load_img
from tensorflow.keras.preprocessing.text import Tokenizer
from tensorflow.keras.preprocessing.sequence import pad_sequences
from tensorflow.keras.utils import to_categorical, plot_model
from tensorflow.keras.models import Model, load_model
from tensorflow.keras.layers import Input, Dense, LSTM, Embedding, add
from tensorflow.keras.layers import Flatten, Dropout, BatchNormalization
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.callbacks import EarlyStopping, LearningRateScheduler
from sklearn.model_selection import train_test_split
from nltk.translate.bleu_score import corpus_bleu
from PIL import Image
from tqdm import tqdm_notebook
from collections import Counter


images_directory = '/kaggle/input/flickr8k/Images/'
captions_path = '/kaggle/input/flickr8k/captions.txt'


def load_captions(file_path):
    with open(file_path, 'r') as f:
        captions = f.readlines()
        captions = [caption.lower() for caption in captions[1:]]
    return captions

def tokenize_captions(captions):
    tokenizer = Tokenizer()
    tokenizer.fit_on_texts(captions)
    return tokenizer

captions = load_captions(captions_path)
captions[:15:3]
```

```
['1000268201_693b08cb0e.jpg,a child in a pink dress is climbing up a set of stairs in an entry way .\n',
 '1000268201_693b08cb0e.jpg,a little girl climbing the stairs to her playhouse .\n',
 '1001773457_577c3a7d70.jpg,a black dog and a tri-colored dog playing with each other on the road .\n',
 '1001773457_577c3a7d70.jpg,two dogs on pavement moving toward each other .\n',
 '1002674143_1b742ab4b8.jpg,a small girl in the grass plays with fingerpaints in front of a white canvas with a rainbow on it .\n']
```

```
def clean_text(text):
    text = re.sub(r'[^\w\s]', '', text)

    text = re.sub(r'\d+', '', text)

    text = re.sub(r'\s+', ' ', text).strip()

    return text

cleaned_captions = [clean_text(caption.split(',')[1]) for caption in captions]
cleaned_captions[:15:2]
```

```
['a child in a pink dress is climbing up a set of stairs in an entry way',
 'a little girl climbing into a wooden playhouse',
 'a little girl in a pink dress going into a wooden cabin',
 'a black dog and a tricolored dog playing with each other on the road',
 'two dogs of different breeds looking at each other on the road',
 'a little girl covered in paint sits in front of a painted rainbow with her hands in a bowl',
 'a small girl in the grass plays with fingerpaints in front of a white canvas with a rainbow on it',
 'young girl with pigtails painting outside in the grass']
```

Cleaning the captions

```
captions_IDs = []
for i in range(len(cleaned_captions)):
    item = captions[i].split(',')[0]+'\t'+'start '+cleaned_captions[i]+' end\n'
    captions_IDs.append(item)
```

```
captions_IDs[:20:3], len(captions_IDs)
```

```
(['1000268201_693b08cb0e.jpg\tstart a child in a pink dress is climbing up a set of stairs in an entry way end\n',
  '1000268201_693b08cb0e.jpg\tstart a little girl climbing the stairs to her playhouse end\n',
  '1001773457_577c3a7d70.jpg\tstart a black dog and a tricolored dog playing with each other on the road end\n',
  '1001773457_577c3a7d70.jpg\tstart two dogs on pavement moving toward each other end\n',
  '1002674143_1b742ab4b8.jpg\tstart a small girl in the grass plays with fingerpaints in front of a white canvas with a rainbow on
 it end\n',
  '1003163366_44323f5815.jpg\tstart a man lays on a bench while his dog sits by him end\n',
  '1003163366_44323f5815.jpg\tstart a shirtless man lies on a park bench with his dog end\n'],
 40455)
```

Visualizing some of the images along with their corresponding captions

```
def visualaization(data, num_of_images):
    captions_dictionary = {}
    for item in data[100:100+(num_of_images)*5]:
        image_id, caption = item.split('\t')
        if image_id not in captions_dictionary:
            captions_dictionary[image_id] = []
        captions_dictionary[image_id].append(caption)
    else:
        list_captions = [x for x in captions_dictionary.items()]

    count = 1
    fig = plt.figure(figsize=(10,20))
    for filename in list(captions_dictionary.keys()):
        captions = captions_dictionary[filename]
        image_load = load_img(images_directory+filename, target_size=(199,199,3))

        ax = fig.add_subplot(num_of_images,2,count,xticks=[],yticks=[])
        ax.imshow(image_load)
        count += 1

        ax = fig.add_subplot(num_of_images,2,count)
        plt.axis('off')
        ax.plot()
        ax.set_xlim(0,1)
        ax.set_ylim(0,len(captions))
        for i, caption in enumerate(captions):
            ax.text(0,i,caption,fontsize=20)
        count += 1
    plt.show()

visualaization(captions_IDs, 5)
```

start two large tan dogs play along a sandy beach end
start two dogs playing together on a beach end
start two dogs playing in the sand at the beach end
start two dogs are making a turn on a soft sand beach end
start two different breeds of brown and white dogs play on the beach end

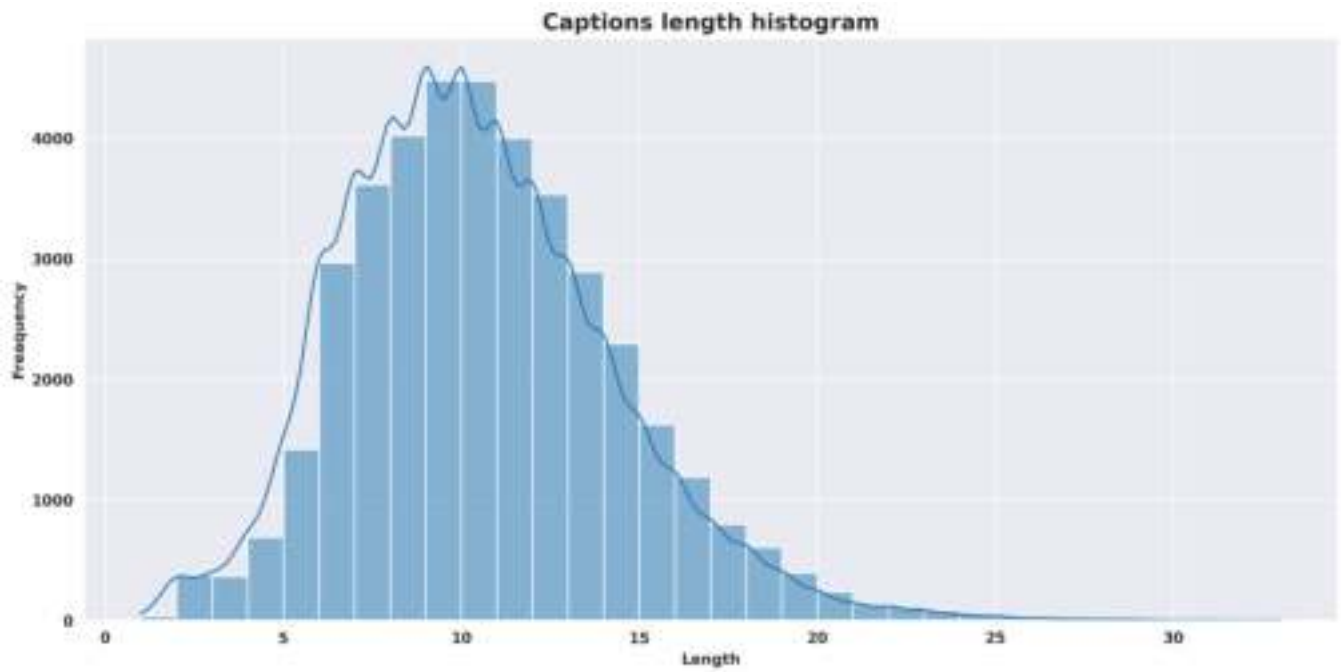
start climber climbing an ice wall end
start a person in blue and red ice climbing with two picks end
start an ice climber scaling a frozen waterfall end
start an ice climber in a blue jacket and black pants is scaling a frozen ice wall end
start a man uses ice picks and crampons to scale ice end

start a wet black dog is carrying a green toy through the grass end
start a dog in grass with a blue item in his mouth end
start a black dog has a blue toy in its mouth end
start a black dog carrying something through the grass end
start a black dog carries a green toy in his mouth as he walks through the grass end

start man and child in yellow kayak end
start a man and young boy ride in a yellow kayak end
start a man and child kayak through gentle waters end
start a man and a little boy in blue life jackets are rowing a yellow canoe end
start a man and a baby are in a yellow kayak on water end

start the chocolate lab jumps too late to get the toy as the black lab captures it in the driveway end
start black dog snaps at red and black object as brown dog lunges end
start a brown and black lab are outside and the black lab is catching a toy in its mouth end
start a black dog and a brown dog play with a red toy on a courtyard end
start a black dog and a brown dog are jumping up to catch a red toy end

```
def captions_length(data):
    plt.figure(figsize=(15, 7), dpi=300)
    sns.set_style('darkgrid')
    sns.histplot(x=[len(x.split(' ')) for x in data], kde=True, binwidth=1)
    plt.title('Captions length histogram', fontsize=15, fontweight='bold')
    plt.xticks(fontweight='bold')
    plt.yticks(fontweight='bold')
    plt.xlabel('Length', fontweight='bold')
    plt.ylabel('Freaquency', fontweight='bold')
    plt.show()

captions_length(cleaned_captions)
```



Tokenizing captions and setting **vocab size**

```
tokenizer = tokenize_captions(cleaned_captions)
vocab_size = len(tokenizer.word_index) + 1
vocab_size
```

```
8586
```

Splitting the data into tain, validation and test sets

```
all_image_ids = os.listdir(images_directory)

train_image_ids, val_image_ids = train_test_split(all_image_ids, test_size=0.15, random_state=42)
val_image_ids, test_image_ids = train_test_split(val_image_ids, test_size=0.1, random_state=42)

train_captions, val_captions, test_captions = [], [], []
for caption in captions_IDs:
    image_id, _ = caption.split('\t')

    if image_id in train_image_ids:
        train_captions.append(caption)

    elif image_id in val_image_ids:
        val_captions.append(caption)

    elif image_id in test_image_ids:
        test_captions.append(caption)

    else:
        print('Unknown image ID !')

train_captions[0], val_captions[0], test_captions[0], len(train_captions)/5, len(val_captions)/5, len(test_captions)/5
```

```
('1000268201_693b08cb0e.jpg\tstart a child in a pink dress is climbing up a set of stairs in an entry way end\n',
 '1001773457_577c3a7d70.jpg\tstart a black dog and a spotted dog are fighting end\n',
 '1042590306_95dea0916c.jpg\tstart a man and woman pose for the camera while another man looks on end\n',
 6877.0,
 1092.0,
 122.0)
```

Extracting Image features using **The InceptionV3** model

```
def preprocess_image(image_path):
    img = load_img(image_path, target_size=(299, 299))
    img = img_to_array(img)
    img = np.expand_dims(img, axis=0)
    img = tf.keras.applications.inception_v3.preprocess_input(img)
    return img

def extract_image_features(model, image_path):
    img = preprocess_image(image_path)
    features = model.predict(img, verbose=0)
    return features

inception_v3_model = InceptionV3(weights = 'imagenet', input_shape=(299, 299, 3))
inception_v3_model.layers.pop()
inception_v3_model = Model(inputs=inception_v3_model.inputs, outputs=inception_v3_model.layers[-2].output)
```

```
Downloading data from https://storage.googleapis.com/tensorflow/keras-applications/inception_v3/inception_v3_weights_tf_dim_orderin
96112376/96112376 [==============================] - 1s 0us/step
```

```
train_image_features, val_image_features, test_image_features = {}, {}, {}  # A Dictionary to store image features with their correspon

pbar = tqdm_notebook(total=len(all_image_ids), position=0, leave=True, colour='green')

for caption in all_image_ids:
    image_id = caption.split('\t')[0]
    image_path = os.path.join(images_directory, image_id)
    image_features = extract_image_features(inception_v3_model, image_path) # Extracting features

    if image_id in train_image_ids:
        train_image_features[image_id] = image_features.flatten()  # Flattening the features
        pbar.update(1)

    elif image_id in val_image_ids:
        val_image_features[image_id] = image_features.flatten()  # Flattening the features
        pbar.update(1)

    elif image_id in test_image_ids:
        test_image_features[image_id] = image_features.flatten()  # Flattening the features
        pbar.update(1)

    else:
        print('Unknown image ID !')

pbar.close()
```

```
  0%|          | 0/8091 [00:00<?, ?it/s]
```

```
def data_generator(captions, image_features, tokenizer, max_caption_length, batch_size):
    num_samples = len(captions)
    image_ids = list(image_features.keys())
    while True:
        np.random.shuffle(image_ids)  # Shuffle image_ids for each epoch
        for start_idx in range(0, num_samples, batch_size):
            end_idx = min(start_idx + batch_size, num_samples)
            X_images, X_captions, y = [], [], []
            for caption in captions[start_idx:end_idx]:
                image_id, caption_text = caption.split('\t')
                caption_text = caption_text.rstrip('\n')
                seq = tokenizer.texts_to_sequences([caption_text])[0] # Tokenizing the caption
                for i in range(1, len(seq)):
                    in_seq, out_seq = seq[:i], seq[i] # X_caption, Y
                    in_seq = pad_sequences([in_seq], maxlen=max_caption_length)[0]
                    out_seq = to_categorical([out_seq], num_classes=vocab_size)[0]
                    X_images.append(image_features[image_id])
                    X_captions.append(in_seq)
                    y.append(out_seq)

            yield [np.array(X_images), np.array(X_captions)], np.array(y)


max_caption_length = max(len(caption.split()) for caption in cleaned_captions) + 1

cnn_output_dim = inception_v3_model.output_shape[1] # 2048

batch_size_train = 270
batch_size_val = 150

train_data_generator = data_generator(train_captions, train_image_features, tokenizer, max_caption_length, batch_size_train)
val_data_generator = data_generator(val_captions, val_image_features, tokenizer, max_caption_length, batch_size_val)
```

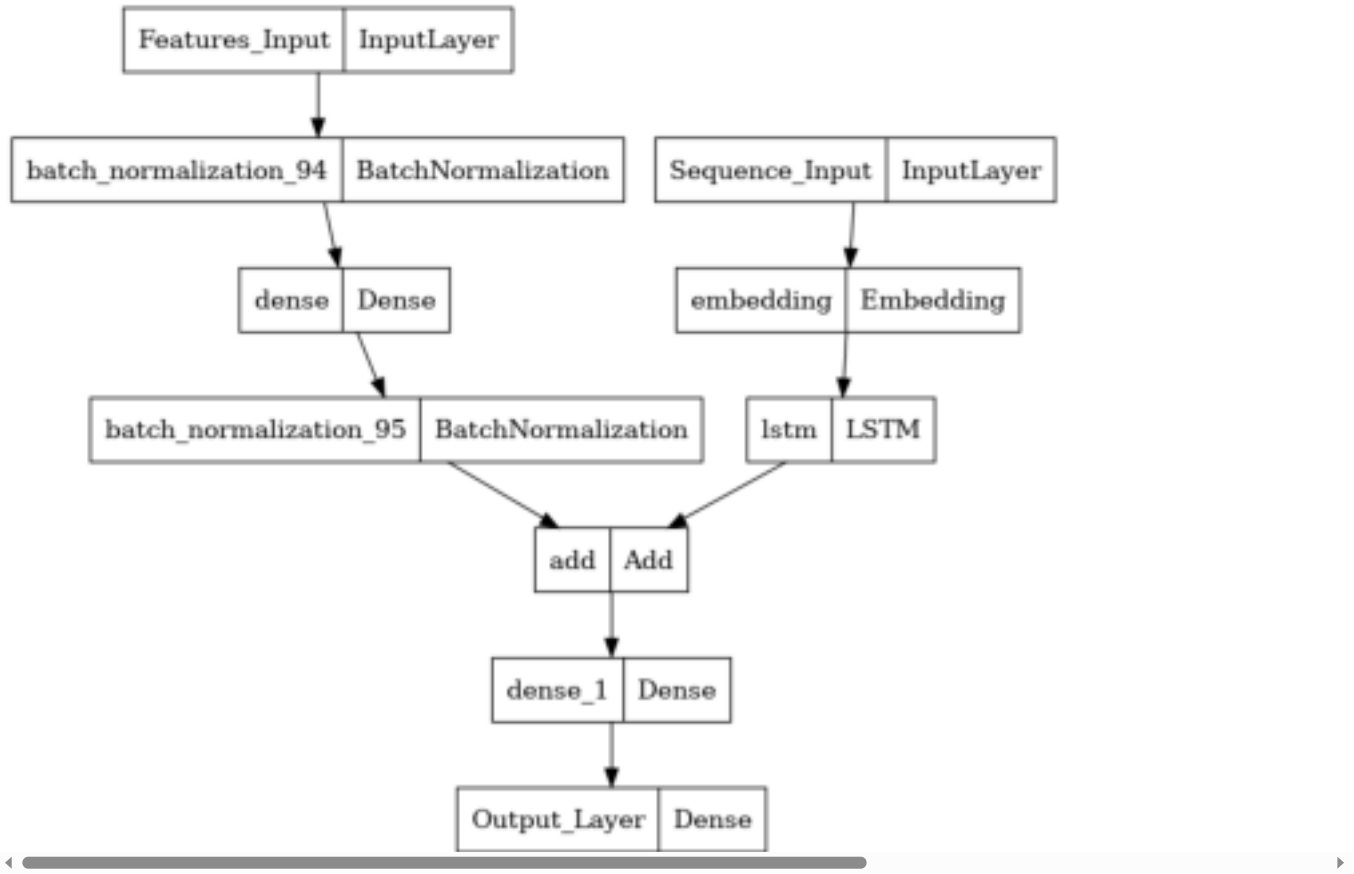
```
sample_batch = next(train_data_generator)
print("Training sample batch shapes:")
print("X_images:", sample_batch[0][0].shape)
print("X_captions:", sample_batch[0][1].shape)
print("y:", sample_batch[1].shape)
print('========================')
sample_batch = next(val_data_generator)
print("Validation sample batch shapes:")
print("X_images:", sample_batch[0][0].shape)
print("X_captions:", sample_batch[0][1].shape)
print("y:", sample_batch[1].shape)
```

```
Training sample batch shapes:
X_images: (3230, 2048)
X_captions: (3230, 34)
y: (3230, 8586)
========================
Validation sample batch shapes:
X_images: (1676, 2048)
X_captions: (1676, 34)
y: (1676, 8586)
```

```
def build_model(vocab_size, max_caption_length, cnn_output_dim):
    input_image = Input(shape=(cnn_output_dim,), name='Features_Input')
    fe1 = BatchNormalization()(input_image)
    fe2 = Dense(256, activation='relu')(fe1) # Adding a Dense layer to the CNN output to match the decoder output size
    fe3 = BatchNormalization()(fe2)

    input_caption = Input(shape=(max_caption_length,), name='Sequence_Input')
    se1 = Embedding(vocab_size, 256, mask_zero=True)(input_caption)
    se2 = LSTM(256)(se1)

    decoder1 = add([fe3, se2])
    decoder2 = Dense(256, activation='relu')(decoder1)
    outputs = Dense(vocab_size, activation='softmax', name='Output_Layer')(decoder2)

    model = Model(inputs=[input_image, input_caption], outputs=outputs, name='Image_Captioning')
    return model

caption_model = build_model(vocab_size, max_caption_length, cnn_output_dim)

optimizer = Adam(learning_rate=0.01, clipnorm=1.0)
caption_model.compile(loss='categorical_crossentropy', optimizer=optimizer)

caption_model.summary()
```

```
Model: "Image_Captioning"
__________________________________________________________________________________________________
 Layer (type)                   Output Shape         Param #     Connected to
==================================================================================================
 Features_Input (InputLayer)    [(None, 2048)]       0           []

 batch_normalization_94 (BatchN  (None, 2048)        8192        ['Features_Input[0][0]']
 ormalization)

 Sequence_Input (InputLayer)    [(None, 34)]         0           []

 dense (Dense)                  (None, 256)          524544      ['batch_normalization_94[0][0]']

 embedding (Embedding)          (None, 34, 256)      2198016     ['Sequence_Input[0][0]']

 batch_normalization_95 (BatchN  (None, 256)         1024        ['dense[0][0]']
 ormalization)

 lstm (LSTM)                    (None, 256)          525312      ['embedding[0][0]']

 add (Add)                      (None, 256)          0           ['batch_normalization_95[0][0]',
                                                                  'lstm[0][0]']

 dense_1 (Dense)                (None, 256)          65792       ['add[0][0]']

 Output_Layer (Dense)           (None, 8586)         2206602     ['dense_1[0][0]']

==================================================================================================
Total params: 5,529,482
Trainable params: 5,524,874
Non-trainable params: 4,608
__________________________________________________________________________________________________
```

```
plot_model(caption_model)
```

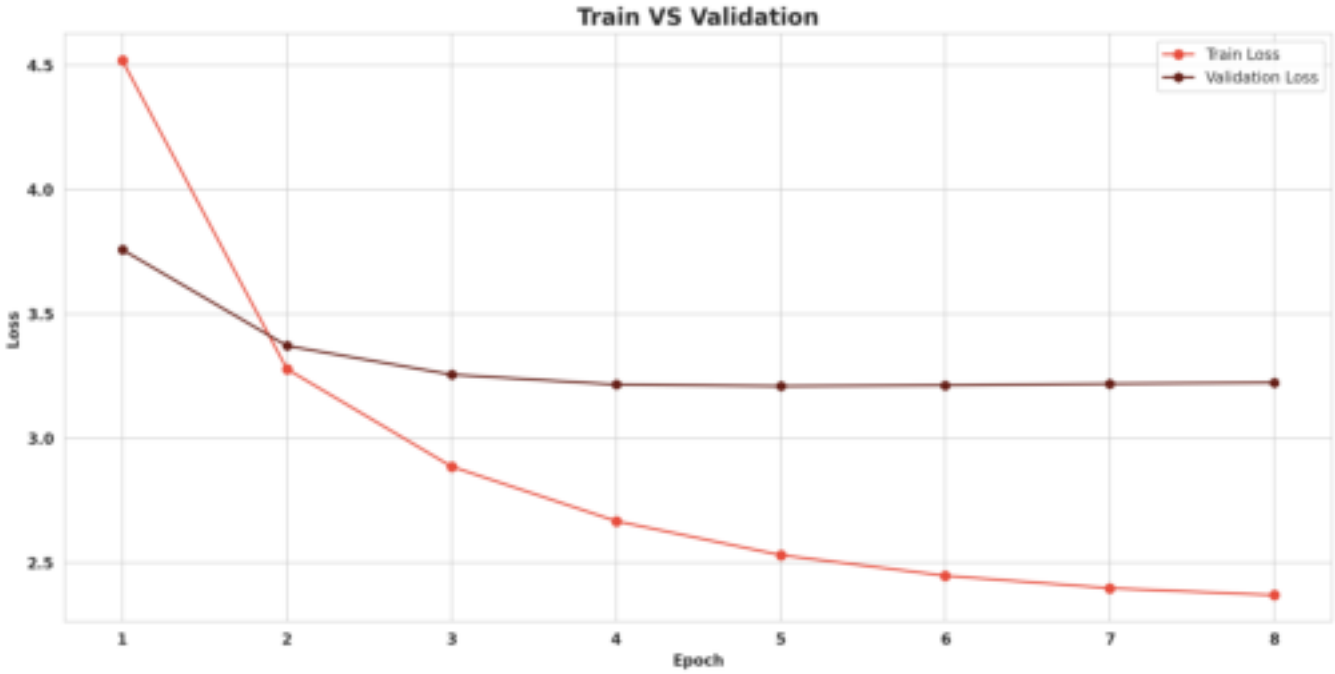



```
early_stopping = EarlyStopping(monitor='val_loss', patience=3, restore_best_weights=True)

def lr_scheduler(epoch, lr):
    return lr * tf.math.exp(-0.6)

lr_schedule = LearningRateScheduler(lr_scheduler)

history = caption_model.fit(train_data_generator, steps_per_epoch=len(train_captions) // batch_size_train,
                        validation_data=val_data_generator, validation_steps=len(val_captions) // batch_size_val,
                        epochs=15, callbacks=[early_stopping, lr_schedule])
```

```
Epoch 1/15
127/127 [==============================] - 59s 412ms/step - loss: 4.5193 - val_loss: 3.7587 - lr: 0.0055
Epoch 2/15
127/127 [==============================] - 46s 363ms/step - loss: 3.2788 - val_loss: 3.3721 - lr: 0.0030
Epoch 3/15
127/127 [==============================] - 46s 367ms/step - loss: 2.8868 - val_loss: 3.2566 - lr: 0.0017
Epoch 4/15
127/127 [==============================] - 46s 364ms/step - loss: 2.6674 - val_loss: 3.2166 - lr: 9.0718e-04
Epoch 5/15
127/127 [==============================] - 46s 365ms/step - loss: 2.5308 - val_loss: 3.2102 - lr: 4.9787e-04
Epoch 6/15
127/127 [==============================] - 46s 361ms/step - loss: 2.4477 - val_loss: 3.2135 - lr: 2.7324e-04
Epoch 7/15
127/127 [==============================] - 46s 364ms/step - loss: 2.3978 - val_loss: 3.2198 - lr: 1.4996e-04
Epoch 8/15
127/127 [==============================] - 46s 362ms/step - loss: 2.3697 - val_loss: 3.2241 - lr: 8.2297e-05
```

Visualizing the model performance

```
plt.figure(figsize=(15, 7), dpi=200)
sns.set_style('whitegrid')
plt.plot([x+1 for x in range(len(history.history['loss']))], history.history['loss'], color='#E74C3C', marker='o')
plt.plot([x+1 for x in range(len(history.history['loss']))], history.history['val_loss'], color='#641E16', marker='h')
plt.title('Train VS Validation', fontsize=15, fontweight='bold')
plt.xticks(fontweight='bold')
plt.yticks(fontweight='bold')
plt.xlabel('Epoch', fontweight='bold')
plt.ylabel('Loss', fontweight='bold')
plt.legend(['Train Loss', 'Validation Loss'], loc='best')
plt.show()
```




```
def greedy_generator(image_features): # A function to generate captions
    in_text = 'start '
    for _ in range(max_caption_length):
        sequence = tokenizer.texts_to_sequences([in_text])[0]
        sequence = pad_sequences([sequence], maxlen=max_caption_length).reshape((1,max_caption_length))
        prediction = caption_model.predict([image_features.reshape(1,cnn_output_dim), sequence], verbose=0)
        idx = np.argmax(prediction)
        word = tokenizer.index_word[idx]
        in_text += ' ' + word
        if word == 'end':
            break

    in_text = in_text.replace('start ', '')
    in_text = in_text.replace(' end', '')13

    return in_text


def beam_search_generator(image_features, K_beams = 3, log = False):
    start = [tokenizer.word_index['start']]

    start_word = [[start, 0.0]]

    for _ in range(max_caption_length):
        temp = []
        for s in start_word:
            sequence  = pad_sequences([s[0]], maxlen=max_caption_length).reshape((1,max_caption_length))

            preds = caption_model.predict([image_features.reshape(1,cnn_output_dim), sequence], verbose=0)

            word_preds = np.argsort(preds[0])[-K_beams:]

            for w in word_preds:

                next_cap, prob = s[0][:], s[1]
                next_cap.append(w)
                if log:
                    prob += np.log(preds[0][w]) # assign a probability to each K words
                else:
                    prob += preds[0][w]
                temp.append([next_cap, prob])

        start_word = temp
        start_word = sorted(start_word, reverse=False, key=lambda l: l[1])

        start_word = start_word[-K_beams:]
```

```
    start_word = start_word[-1][0]
    captions_ = [tokenizer.index_word[i] for i in start_word]

    final_caption = []

    for i in captions_:
        if i != 'end':
            final_caption.append(i)
        else:
            break

    final_caption = ' '.join(final_caption[1:])
    return final_caption


def BLEU_score(actual, greedy, beam_search):
    score_greedy_1 = corpus_bleu(actual, greedy, weights=(0.3, 0.3, 0.3, 0))
    score_greedy_2 = corpus_bleu(actual, greedy, weights=(0.25, 0.25, 0.25, 0.25))
    score_BS_1 = corpus_bleu(actual, beam_search, weights=(0.3, 0.3, 0.3, 0))
    score_BS_2 = corpus_bleu(actual, beam_search, weights=(0.25, 0.25, 0.25, 0.25))

    return [
        (f'BLEU-2 Greedy: {round(score_BS_2, 5)}'),
        (f'BLEU-1 Greedy: {round(score_BS_1, 5)}'),
        (f'Greedy: {greedy[0]}'),
        (f'BLEU-2 Beam Search: {round(score_greedy_2, 5)}'),
        (f'BLEU-1 Beam Search: {round(score_greedy_1, 5)}'),
        (f'Beam Search:  {beam_search[0]}')
    ]


generated_captions = {}

pbar = tqdm_notebook(total=len(test_image_features), position=0, leave=True, colour='green')
for image_id in test_image_features:
    cap = greedy_generator(test_image_features[image_id])
    generated_captions[image_id] = cap
    pbar.update(1)

pbar.close()
```

```
  0%|          | 0/122 [00:00<?, ?it/s]
```

Visualizing some of the **test images** along with their corresponding **generated captions**

```
def visualization(data, greedy_caps, beamS_generator, evaluator, num_of_images):
    keys = list(data.keys()) # List of all test images
    images = [np.random.choice(keys) for i in range(num_of_images)] # Randomly selected images

    count = 1
    fig = plt.figure(figsize=(6,20))
    for filename in images:
        actual_cap = data[filename]
        actual_cap = [x.replace("start ", "") for x in actual_cap] # Removing the start token
        actual_cap = [x.replace(" end", "") for x in actual_cap] # Removing the end token

        greedy_cap = greedy_caps[filename]
        beamS_cap = beamS_generator(test_image_features[filename])

        caps_with_score = evaluator(actual_cap, [greedy_cap]*(len(actual_cap)), [beamS_cap]*(len(actual_cap)))

        image_load = load_img(images_directory+filename, target_size=(199,199,3))
        ax = fig.add_subplot(num_of_images,2,count,xticks=[],yticks=[])
        ax.imshow(image_load)
        count += 1

        ax = fig.add_subplot(num_of_images,2,count)
        plt.axis('off')
        ax.plot()
        ax.set_xlim(0,1)
        ax.set_ylim(0,len(caps_with_score))
        for i, text in enumerate(caps_with_score):
            ax.text(0,i,text,fontsize=10)
        count += 1
    plt.show()

visualization(test_actual_captions, generated_captions, beam_search_generator, BLEU_score, 7)
```

Beam Search: a man is performing a trick on a ramp

BLEU-1 Beam Search: 0.70765

BLEU-2 Beam Search: 0.74963

Greedy: a man in a red shirt is riding a jump

BLEU-1 Greedy: 0.73735

BLEU-2 Greedy: 0.77576

Beam Search: a young boy jumps into a pool

BLEU-1 Beam Search: 0.7062

BLEU-2 Beam Search: 0.74835

Greedy: a boy in a blue suit is jumping into a pool

BLEU-1 Greedy: 0.78607

BLEU-2 Greedy: 0.81825

Beam Search: a soccer player kicks a soccer ball in the air

BLEU-1 Beam Search: 0.68477

BLEU-2 Beam Search: 0.72938

Greedy: a young boy in a blue shirt is kicking a soccer ball

BLEU-1 Greedy: 0.7058

BLEU-2 Greedy: 0.748

Beam Search: a man in a red shirt is standing on a bench

BLEU-1 Beam Search: 0.69986

BLEU-2 Beam Search: 0.74275

Greedy: a man in a white shirt is standing on a bench