Loading libraries

```
!pip install openpyxl  --quiet
```

```
import numpy as np
import matplotlib.pyplot as plt
import seaborn as sns
import pandas as pd
from collections import defaultdict
import string
import tensorflow as tf
import re
import os
import time
from tensorflow import keras
from tensorflow.keras.layers import Dense, Input
from tensorflow.keras.optimizers import Adam
from tensorflow.keras.models import Model
from tensorflow.keras.callbacks import ModelCheckpoint
from sklearn.preprocessing import OneHotEncoder
from sklearn.model_selection import train_test_split
```

```
ENCODER_LEN = 100
DECODER_LEN = 20
BATCH_SIZE = 64
BUFFER_SIZE = BATCH_SIZE*8
```

Loading Data

```
from google.colab import files
files.upload()
```

Choose files Inshorts Cle… Data 3.xlsx

- **Inshorts Cleaned Data 3.xlsx**(application/vnd.openxmlformats-officedocument.spreadsheetml.sheet) - 12430903 bytes, last modified: 05/12/2022 - 100% done

```
Saving Inshorts Cleaned Data 3.xlsx to Inshorts Cleaned Data 3.xlsx
```

```
News_Data = pd.read_excel("Inshorts Cleaned Data 3.xlsx")
```

```
News_Data.head()
```

	Headline	Short	Source	Time	Publish Date
0	4 ex-bank officials booked for cheating bank o...	The CBI on Saturday booked four former officia...	The New Indian Express	09:25:00	2017-03-26
1	Supreme Court to go paperless in 6 months: CJI	Chief Justice JS Khehar has said the Supreme C...	Outlook	22:18:00	2017-03-25
2	At least 3 killed, 30 injured in blast in Sylh...	At least three people were killed, including a...	Hindustan Times	23:39:00	2017-03-25

```
News_Data.drop(['Source ', 'Time ', 'Publish Date'], axis=1, inplace=True)
```

```
News_Data.head()
```

	Headline	Short
0	4 ex-bank officials booked for cheating bank o...	The CBI on Saturday booked four former officia...
1	Supreme Court to go paperless in 6 months: CJI	Chief Justice JS Khehar has said the Supreme C...
2	At least 3 killed, 30 injured in blast in Sylh...	At least three people were killed, including a...
3	Why has Reliance been barred from trading in f...	Mukesh Ambani-led Reliance Industries (RIL) wa...
4	Was stopped from entering my own studio at Tim...	TV news anchor Arnab Goswami has said he was t...

Pre Processing

we perform preprocessing that is required to train any NLP model. We fit a Tokenizer on the sequences

```
article = News_Data['Short']
summary = News_Data['Headline']
article = article.apply(lambda x: '<SOS> ' + x + ' <EOS>')
summary = summary.apply(lambda x: '<SOS> ' + x + ' <EOS>')
```

```
def preprocess(text):
    text = re.sub(r"&.[1-9]+;"," ",text)
    return text
article = article.apply(lambda x: preprocess(x))
summary = summary.apply(lambda x: preprocess(x))
```

```
filters = '!"#$%&()*+,-./:;=?@[\\]^_`{|}~\t\n'
oov_token = '<unk>'
article_tokenizer = tf.keras.preprocessing.text.Tokenizer(oov_token=oov_token)
summary_tokenizer = tf.keras.preprocessing.text.Tokenizer(filters=filters, oov_token=oov_token)
article_tokenizer.fit_on_texts(article)
summary_tokenizer.fit_on_texts(summary)
inputs = article_tokenizer.texts_to_sequences(article)
targets = summary_tokenizer.texts_to_sequences(summary)
```

```
ENCODER_VOCAB = len(article_tokenizer.word_index) + 1
DECODER_VOCAB = len(summary_tokenizer.word_index) + 1
```

```
print(ENCODER_VOCAB, DECODER_VOCAB)
```

```
76362 29661
```

Tokenization API for TensorFlow essentially takes care of all aspects of data preparation and cleaning. To provide the model a more universal input, there is still one more step that involves padding or truncating the sequences to a predetermined length.

```
inputs = tf.keras.preprocessing.sequence.pad_sequences(inputs, maxlen=ENCODER_LEN, padding='post', truncating='post')
targets = tf.keras.preprocessing.sequence.pad_sequences(targets, maxlen=DECODER_LEN, padding='post', truncating='post')
inputs = tf.cast(inputs, dtype=tf.int64)
targets = tf.cast(targets, dtype=tf.int64)
```

Finally, we batch and shuffle the data to make it simple to obtain it for model training. We accelerate the calculation of these operations using the TensorFlow Dataset API.

```
dataset = tf.data.Dataset.from_tensor_slices((inputs, targets)).shuffle(BUFFER_SIZE).batch(BATCH_SIZE)
```

Postal Encodings

These procedures are in charge of getting the input sequences' positional encodings. Positional Encodings essentially creates an idea of ordering among the input words because the Transformer's self-attention mechanism disregards it.

MASKING

The external padding that is added to sequences that are shorter than maxlen is ignored by padding mask.

In order to prevent words that follow a specific current word from influencing the prediction of the current word, look-ahead mask must be used.

We also implement scale dot product.As the foundation for the model's computation of attention, this is one of the most crucial tasks in creating the Transformer.

```
def get_angles(position, i, d_model):
    angle_rates = 1 / np.power(10000, (2 * (i // 2)) / np.float32(d_model))
    return position * angle_rates

def positional_encoding(position, d_model):
    angle_rads = get_angles(
        np.arange(position)[:, np.newaxis],
        np.arange(d_model)[np.newaxis, :],
        d_model
    )

    angle_rads[:, 0::2] = np.sin(angle_rads[:, 0::2])
    angle_rads[:, 1::2] = np.cos(angle_rads[:, 1::2])

    pos_encoding = angle_rads[np.newaxis, ...]

    return tf.cast(pos_encoding, dtype=tf.float32)

def create_padding_mask(seq):
    seq = tf.cast(tf.math.equal(seq, 0), tf.float32)
    return seq[:, tf.newaxis, tf.newaxis, :]

def create_look_ahead_mask(size):
    mask = 1 - tf.linalg.band_part(tf.ones((size, size)), -1, 0)
    return mask

def scaled_dot_product_attention(q, k, v, mask):
    matmul_qk = tf.matmul(q, k, transpose_b=True)

    dk = tf.cast(tf.shape(k)[-1], tf.float32)
    scaled_attention_logits = matmul_qk / tf.math.sqrt(dk)

    if mask is not None:
        scaled_attention_logits += (mask * -1e9)

    attention_weights = tf.nn.softmax(scaled_attention_logits, axis=-1)

    output = tf.matmul(attention_weights, v)
    return output, attention_weights
```

Multi Head Attention

Multi-Head Attention is what we refer to as a TensorFlow Custom Layer. Here, we divide the inputs into several heads, calculate the attention weights using scaled dot-product attention, and then combine the output from all the heads.

```
class MultiHeadAttention(tf.keras.layers.Layer):
    def __init__(self, d_model, num_heads):
        super(MultiHeadAttention, self).__init__()
        self.num_heads = num_heads
        self.d_model = d_model

        assert d_model % self.num_heads == 0

        self.depth = d_model // self.num_heads

        self.wq = tf.keras.layers.Dense(d_model)
        self.wk = tf.keras.layers.Dense(d_model)
        self.wv = tf.keras.layers.Dense(d_model)

        self.dense = tf.keras.layers.Dense(d_model)

    def split_heads(self, x, batch_size):
        x = tf.reshape(x, (batch_size, -1, self.num_heads, self.depth))
        return tf.transpose(x, perm=[0, 2, 1, 3])
    def call(self, v, k, q, mask):
        batch_size = tf.shape(q)[0]

        q = self.wq(q)
        k = self.wk(k)
        v = self.wv(v)

        q = self.split_heads(q, batch_size)
        k = self.split_heads(k, batch_size)
        v = self.split_heads(v, batch_size)

        # Fazer todas as projeções lineares no batch
        scaled_attention, attention_weights = scaled_dot_product_attention(
            q, k, v, mask)

        # Aplicando a atenção a todos os vetores projetados no batch
        scaled_attention = tf.transpose(scaled_attention, perm=[0, 2, 1, 3])

        # Concatenar
        concat_attention = tf.reshape(scaled_attention, (batch_size, -1, self.d_model))
        output = self.dense(concat_attention)

        return output, attention_weights

def point_wise_feed_forward_network(d_model, dff):
    # Implementação da equação FNN
    return tf.keras.Sequential([
        tf.keras.layers.Dense(dff, activation='relu'),
        tf.keras.layers.Dense(d_model)
    ])
```

Encoder and Decoder

This layer is in charge of directly engaging with inputs and outputs. In this case, the positional encodings are enhanced by the addition of the input embeddings.

```
class EncoderLayer(tf.keras.layers.Layer):

    def __init__(self, d_model, num_heads, dff, rate=0.1):
        super(EncoderLayer, self).__init__()

        self.mha = MultiHeadAttention(d_model, num_heads)
        self.ffn = point_wise_feed_forward_network(d_model, dff)

        self.layernorm1 = tf.keras.layers.LayerNormalization(epsilon=1e-6)
        self.layernorm2 = tf.keras.layers.LayerNormalization(epsilon=1e-6)

        self.dropout1 = tf.keras.layers.Dropout(rate)
        self.dropout2 = tf.keras.layers.Dropout(rate)

    def call(self, x, training, mask):
        attn_output, _ = self.mha(x, x, x, mask)
        attn_output = self.dropout1(attn_output, training=training)
        out1 = self.layernorm1(x + attn_output)

        ffn_output = self.ffn(out1)
        ffn_output = self.dropout2(ffn_output, training=training)
        out2 = self.layernorm2(out1 + ffn_output)

        return out2
```

```
class DecoderLayer(tf.keras.layers.Layer):
    def __init__(self, d_model, num_heads, dff, rate=0.1):
        super(DecoderLayer, self).__init__()

        self.mha1 = MultiHeadAttention(d_model, num_heads)
        self.mha2 = MultiHeadAttention(d_model, num_heads)

        self.ffn = point_wise_feed_forward_network(d_model, dff)

        self.layernorm1 = tf.keras.layers.LayerNormalization(epsilon=1e-6)
        self.layernorm2 = tf.keras.layers.LayerNormalization(epsilon=1e-6)
        self.layernorm3 = tf.keras.layers.LayerNormalization(epsilon=1e-6)

        self.dropout1 = tf.keras.layers.Dropout(rate)
        self.dropout2 = tf.keras.layers.Dropout(rate)
        self.dropout3 = tf.keras.layers.Dropout(rate)


    def call(self, x, enc_output, training, look_ahead_mask, padding_mask):
        attn1, attn_weights_block1 = self.mha1(x, x, x, look_ahead_mask)
        attn1 = self.dropout1(attn1, training=training)
        out1 = self.layernorm1(attn1 + x)

        attn2, attn_weights_block2 = self.mha2(enc_output, enc_output, out1, padding_mask)
        attn2 = self.dropout2(attn2, training=training)
        out2 = self.layernorm2(attn2 + out1)

        ffn_output = self.ffn(out2)
        ffn_output = self.dropout3(ffn_output, training=training)
        out3 = self.layernorm3(ffn_output + out2)

        return out3, attn_weights_block1, attn_weights_block2
```

```
class Encoder(tf.keras.layers.Layer):
    def __init__(self, num_layers, d_model, num_heads, dff, input_vocab_size, maximum_position_encoding, rate=0.1):
        super(Encoder, self).__init__()

        self.d_model = d_model
        self.num_layers = num_layers

        self.embedding = tf.keras.layers.Embedding(input_vocab_size, d_model)
        self.pos_encoding = positional_encoding(maximum_position_encoding, self.d_model)

        self.enc_layers = [EncoderLayer(d_model, num_heads, dff, rate) for _ in range(num_layers)]

        self.dropout = tf.keras.layers.Dropout(rate)
    def call(self, x, training, mask):
        seq_len = tf.shape(x)[1]

        x = self.embedding(x)
        x *= tf.math.sqrt(tf.cast(self.d_model, tf.float32))
        x += self.pos_encoding[:, :seq_len, :]

        x = self.dropout(x, training=training)

        for i in range(self.num_layers):
            x = self.enc_layers[i](x, training, mask)

        return x

class Decoder(tf.keras.layers.Layer):

    def __init__(self, num_layers, d_model, num_heads, dff, target_vocab_size, maximum_position_encoding, rate=0.1):
        super(Decoder, self).__init__()

        self.d_model = d_model
        self.num_layers = num_layers

        self.embedding = tf.keras.layers.Embedding(target_vocab_size, d_model)
        self.pos_encoding = positional_encoding(maximum_position_encoding, d_model)

        self.dec_layers = [DecoderLayer(d_model, num_heads, dff, rate) for _ in range(num_layers)]
        self.dropout = tf.keras.layers.Dropout(rate)

    def call(self, x, enc_output, training, look_ahead_mask, padding_mask):
        seq_len = tf.shape(x)[1]
        attention_weights = {}

        x = self.embedding(x)
        x *= tf.math.sqrt(tf.cast(self.d_model, tf.float32))
        x += self.pos_encoding[:, :seq_len, :]

        x = self.dropout(x, training=training)

        for i in range(self.num_layers):
            x, block1, block2 = self.dec_layers[i](x, enc_output, training, look_ahead_mask, padding_mask)

            attention_weights['decoder_layer{}_block1'.format(i+1)] = block1
            attention_weights['decoder_layer{}_block2'.format(i+1)] = block2

        return x, attention_weights
```

Stacking all the layers in the model.

```
class Transformer(tf.keras.Model):
    def __init__(self, num_layers, d_model, num_heads, dff, input_vocab_size, target_vocab_size, pe_input, pe_target, rate=0.1):
        super(Transformer, self).__init__()

        self.encoder = Encoder(num_layers, d_model, num_heads, dff, input_vocab_size, pe_input, rate)
        self.decoder = Decoder(num_layers, d_model, num_heads, dff, target_vocab_size, pe_target, rate)

        self.final_layer = tf.keras.layers.Dense(target_vocab_size)

    def call(self, inp, tar, training, enc_padding_mask, look_ahead_mask, dec_padding_mask):
        enc_output = self.encoder(inp, training, enc_padding_mask)

        dec_output, attention_weights = self.decoder(tar, enc_output, training, look_ahead_mask, dec_padding_mask)

        final_output = self.final_layer(dec_output)

        return final_output, attention_weights
```

The output layer with vocab size units is added to the Decoder. This class's output will be used for loss estimation or inference during training.

```
num_layers = 3
d_model = 128
dff = 512
num_heads = 4
dropout_rate = 0.2
EPOCHS = 15
```

Custom Learning Rate

custom learning rate scheduler helps faster convergence

```
class CustomSchedule(tf.keras.optimizers.schedules.LearningRateSchedule):
    def __init__(self, d_model, warmup_steps=4000):
        super(CustomSchedule, self).__init__()

        self.d_model = d_model
        self.d_model = tf.cast(self.d_model, tf.float32)

        self.warmup_steps = warmup_steps

    def __call__(self, step):
        arg1 = tf.math.rsqrt(step)
        arg2 = step * (self.warmup_steps ** -1.5)

        return tf.math.rsqrt(self.d_model) * tf.math.minimum(arg1, arg2)
```

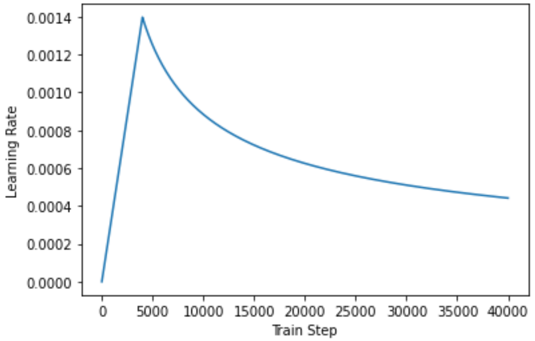
```
learning_rate = CustomSchedule(d_model)

optimizer = tf.keras.optimizers.Adam(learning_rate, beta_1=0.9, beta_2=0.98, epsilon=1e-9)
```

```
temp_learning_rate_schedule = CustomSchedule(d_model)

plt.plot(temp_learning_rate_schedule(tf.range(40000, dtype=tf.float32)))
plt.ylabel("Learning Rate")
plt.xlabel("Train Step")
```

```
Text(0.5, 0, 'Train Step')
```



```
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_sum(loss_)/tf.reduce_sum(mask)


def accuracy_function(real, pred):
    accuracies = tf.equal(real, tf.argmax(pred, axis=2))
    #accuracies = tf.cast(accuracies, dtype= tf.float32)

    mask = tf.math.logical_not(tf.math.equal(real, 0))
    accuracies = tf.math.logical_and(mask, accuracies)

    accuracies = tf.cast(accuracies, dtype=tf.float32)
    mask = tf.cast(mask, dtype=tf.float32)
    return tf.reduce_sum(accuracies)/tf.reduce_sum(mask)
```

```
train_loss = tf.keras.metrics.Mean(name='train_loss')
train_accuracy = tf.keras.metrics.Mean(name='train_accuracy')
```

Training the model

```
transformer = Transformer(
    num_layers=num_layers,
    d_model=d_model,
    num_heads=num_heads,
    dff=dff,
    input_vocab_size=ENCODER_VOCAB,
    target_vocab_size=DECODER_VOCAB,
    pe_input=1000,
    pe_target=1000,
    rate=dropout_rate)
```

```
def create_masks(inp, tar):
    enc_padding_mask = create_padding_mask(inp)
    dec_padding_mask = create_padding_mask(inp)

    look_ahead_mask = create_look_ahead_mask(tf.shape(tar)[1])
    dec_target_padding_mask = create_padding_mask(tar)
    combined_mask = tf.maximum(dec_target_padding_mask, look_ahead_mask)

    return enc_padding_mask, combined_mask, dec_padding_mask
```

```
checkpoint_path = "checkpoints"

ckpt = tf.train.Checkpoint(transformer=transformer, optimizer=optimizer)

ckpt_manager = tf.train.CheckpointManager(ckpt, checkpoint_path, max_to_keep=5)

if ckpt_manager.latest_checkpoint:
    ckpt.restore(ckpt_manager.latest_checkpoint)
    print ('Latest checkpoint restored!!')
```

```
@tf.function
def train_step(inp, tar):
    tar_inp = tar[:, :-1]
    tar_real = tar[:, 1:]

    enc_padding_mask, combined_mask, dec_padding_mask = create_masks(inp, tar_inp)

    with tf.GradientTape() as tape:
        predictions, _ = transformer(
            inp, tar_inp,
            True,
            enc_padding_mask,
            combined_mask,
            dec_padding_mask
        )
        loss = loss_function(tar_real, predictions)

    gradients = tape.gradient(loss, transformer.trainable_variables)
    optimizer.apply_gradients(zip(gradients, transformer.trainable_variables))

    train_loss(loss)
    train_accuracy(accuracy_function(tar_real, predictions))
```

```
for epoch in range(EPOCHS):
    start = time.time()

    train_loss.reset_states()

    # inp -> texto original, tar -> texto que vai ser gerado (sumarização do texto da notícia)
    for (batch, (inp, tar)) in enumerate(dataset):
        train_step(inp, tar)

        if batch % 100 == 0:
            print(f'Epoch {epoch + 1} Batch {batch} Loss {train_loss.result():.4f} Accuracy {train_accuracy.result():.4f}')

    if (epoch + 1) % 5 == 0:
        ckpt_save_path = ckpt_manager.save()
        print ('Saving checkpoint for epoch {} at {}'.format(epoch+1, ckpt_save_path))

    print(f'Epoch {epoch + 1} Loss {train_loss.result():.4f} Accuracy {train_accuracy.result():.4f}')
    print ('Time taken for 1 epoch: {} secs\n'.format(time.time() - start))
```

```
Epoch 14 Batch 700 Loss 3.1310 Accuracy 0.3283
Epoch 14 Batch 800 Loss 3.0972 Accuracy 0.3300
Epoch 14 Loss 3.0769 Accuracy 0.3311
Time taken for 1 epoch: 67.15378952026367 secs

Epoch 15 Batch 0 Loss 3.9455 Accuracy 0.3311
Epoch 15 Batch 100 Loss 3.3397 Accuracy 0.3322
Epoch 15 Batch 200 Loss 3.2523 Accuracy 0.3334
Epoch 15 Batch 300 Loss 3.1952 Accuracy 0.3347
Epoch 15 Batch 400 Loss 3.1637 Accuracy 0.3360
Epoch 15 Batch 500 Loss 3.1144 Accuracy 0.3375
Epoch 15 Batch 600 Loss 3.0732 Accuracy 0.3391
Epoch 15 Batch 700 Loss 3.0342 Accuracy 0.3407
Epoch 15 Batch 800 Loss 3.0000 Accuracy 0.3423
Saving checkpoint for epoch 15 at checkpoints/ckpt-3
Epoch 15 Loss 2.9811 Accuracy 0.3433
Time taken for 1 epoch: 67.68230056762695 secs
```

Testing the Model

```
def evaluate(input_article):
    input_article = article_tokenizer.texts_to_sequences([input_article])
    input_article = tf.keras.preprocessing.sequence.pad_sequences(input_article, maxlen=ENCODER_LEN,
                                                                   padding='post', truncating='post')

    encoder_input = tf.expand_dims(input_article[0], 0)

    decoder_input = [summary_tokenizer.word_index['<sos>']]
    output = tf.expand_dims(decoder_input, 0)

    for i in range(DECODER_LEN):
        enc_padding_mask, combined_mask, dec_padding_mask = create_masks(encoder_input, output)

        predictions, attention_weights = transformer(
            encoder_input,
            output,
            False,
            enc_padding_mask,
            combined_mask,
            dec_padding_mask
        )

        predictions = predictions[: ,-1:, :]
        predicted_id = tf.cast(tf.argmax(predictions, axis=-1), tf.int32)

        if predicted_id == summary_tokenizer.word_index['<eos>']:
            return tf.squeeze(output, axis=0), attention_weights

        output = tf.concat([output, predicted_id], axis=-1)

    return tf.squeeze(output, axis=0), attention_weights
```

Results

```
def summarize(input_article):
    summarized = evaluate(input_article=input_article)[0].numpy()
    summarized = np.expand_dims(summarized[1:], 0)
    return summary_tokenizer.sequences_to_texts(summarized)[0]
```

```
article[5]
```

```
'<SOS> A new trailer for the upcoming superhero film  Justice League  was released on Saturday. Based on the DC Comi
cs superhero team, the film stars Ben Affleck as  Batman , Gal Gadot as  Wonder Woman , Ezra Miller as  The Flash  a
nd Jason Momoa as  Aquaman . Directed by Zack Snyder, the film is scheduled to release on November 17, 2017. <EOS>'
```

```
print("Real Headline : ", summary[5][5:-5],"\n Predicted Summary : ", summarize(article[5]))
```

```
Real Headline :   New trailer of  Justice League  released
 Predicted Summary :  new trailer for justice league released
```

```
article[43]
```

```
'<SOS> Actor Ranbir Kapoor has penned a special letter to Shah Rukh Khan s wife Gauri Khan to thank her for designin
g his home. The letter has been shared by Gauri on Instagram. Gauri, who is an interior designer, has designed Ranbi
r Kapoor s house in Bandra, Mumbai. Ranbir will reportedly move into his new home in the month of October.  <EOS>'
```

```
print("Real Headline : ", summary[43][5:-5],"\nPredicted Summary : ", summarize(article[43]))
```

```
Real Headline :   Ranbir Kapoor pens special letter to SRK s wife Gauri Khan
Predicted Summary :  ranbir kapoor pens letter to srk s wife
```

```
article[12]
```

```
'<SOS> Thousands of people on Saturday took to the streets in London to protest against the UK s decision to leave t
he European Union. Demanding continuation of benefits of remaining in the EU, the protesters said that they were the
48% who voted to remain in the EU during the 2016 referendum. The Brexit process is to be initiated on March 29. <EO
S>'
```

```
print("Real Headline : ", summary[12][5:-5],"\nPredicted Summary : ", summarize(article[12]))
```

```
Real Headline :   Thousands march in London to protest against Brexit
Predicted Summary :  london protests against uk on brexit issue
```

✓ 1s completed at 14:19