Neural machine translation with attention

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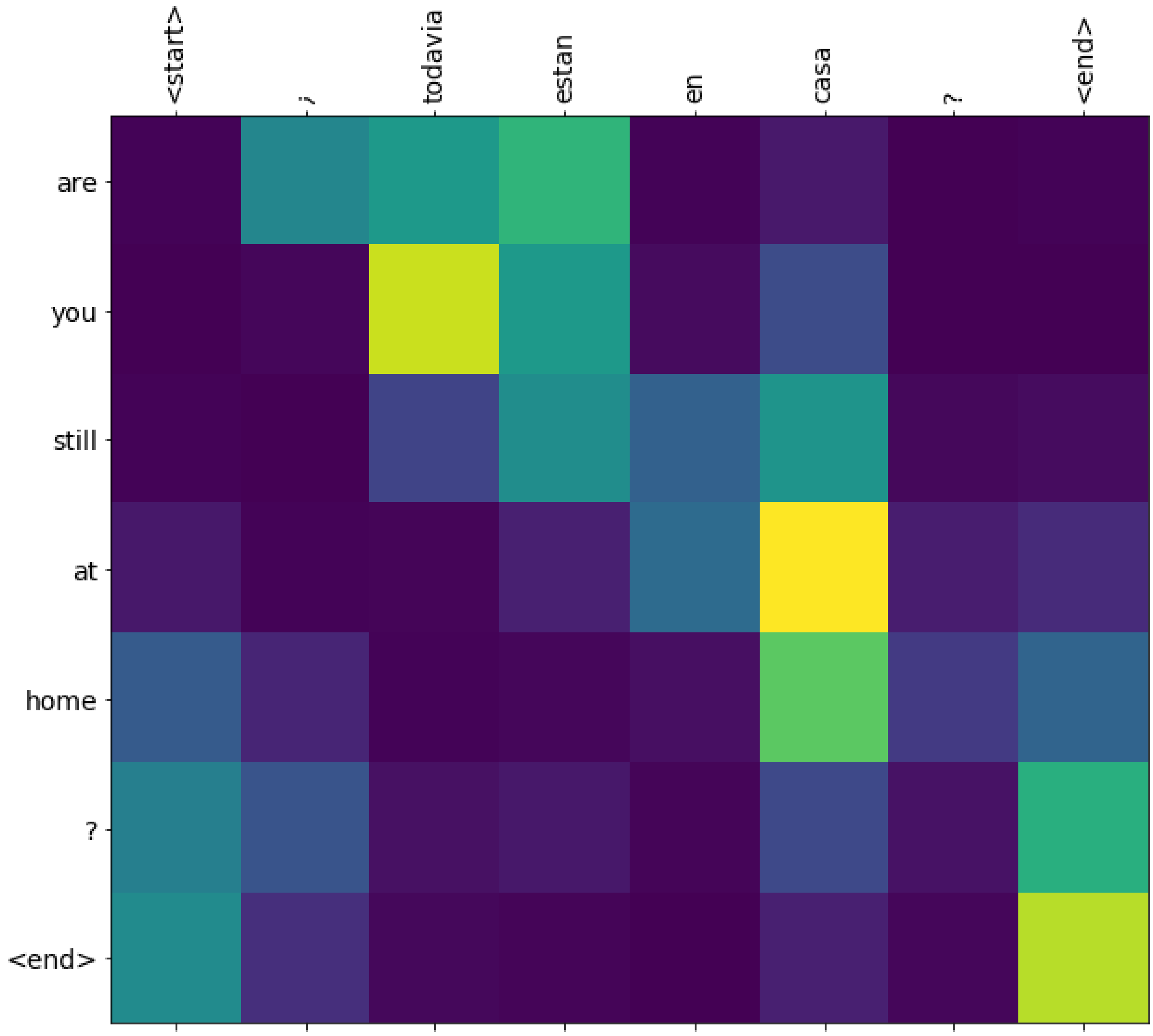
This notebook trains a sequence to sequence (seq2seq) model for Spanish to English translation. This is an advanced example that assumes some knowledge of sequence to sequence models.

After training the model in this notebook, you will be able to input a Spanish sentence, such as *"¿todavia estan en casa?", *and return the English translation: *"are you still at home?"*

The translation quality is reasonable for a toy example, but the generated attention plot is perhaps more interesting. This shows which parts of the input sentence has the model's attention while translating:



Note: This example takes approximately 10 minutes to run on a single P100 GPU.

```
import tensorflow as tf
import sentencepiece as spm

import matplotlib.pyplot as plt
import matplotlib.ticker as ticker
from sklearn.model_selection import train_test_split

import unicodedata
import re
import numpy as np
import os
import io
import time
```

Download and prepare the dataset

We'll use a language dataset provided by http://www.manythings.org/anki/. This dataset contains language translation pairs in the format:

```
May I borrow this book?    ¿Puedo tomar prestado este libro?
```

There are a variety of languages available, but we'll use the English-Spanish dataset. For convenience, we've hosted a copy of this dataset on Google Cloud, but you can also download your own copy. After downloading the dataset, here are the steps we'll take to prepare the data:

1. Add a *start* and *end* token to each sentence.
2. Clean the sentences by removing special characters.
3. Create a word index and reverse word index (dictionaries mapping from word → id and id → word).
4. Pad each sentence to a maximum length.

```
from google.colab import drive
drive.mount('/content/drive')
```

```
Drive already mounted at /content/drive; to attempt to forcibly remount, call drive.mount("/
```

```
# Download the file
path_to_zip = tf.keras.utils.get_file(
    'spa-eng.zip', origin='http://storage.googleapis.com/download.tensorflow.org/data/spa-eng.zip',
    extract=True)

path_to_file = "/content/구어체(1).txt"
```

```
spm.SentencePieceTrainer.Train('--input=구어체(1).txt --model_prefix=kor-eng --vocab_size=32000 --r
```

```
sp = spm.SentencePieceProcessor()
vocab_file = "kor-eng.model"
sp.load(vocab_file)
```

```
True
```

```
with open('구어체(1).txt', 'r', encoding='UTF-8') as f:
  with open('구어체(2).txt', 'w', encoding='UTF-8') as kef:
    for line in f:
      kef.write(str(sp.encode_as_pieces(line)) + '₩n')
```

```
# Converts the unicode file to ascii
def unicode_to_ascii(s):
  return ''.join(c for c in unicodedata.normalize('NFD', s)
      if unicodedata.category(c) != 'Mn')


def preprocess_sentence(w):
  #w = unicode_to_ascii(w.lower().strip())
  w = w.lower().strip()
```

```
  # creating a space between a word and the punctuation following it
  # eg: "he is a boy." => "he is a boy ."
  # Reference:- https://stackoverflow.com/questions/3645931/python-padding-punctuation-with-white-s
  w = re.sub(r"([?.!,¿])", r" ₩1 ", w)
  w = re.sub(r'[" "]+', " ", w)

  # replacing everything with space except (a-z, A-Z, ".", "?", "!", ",")
  w = re.sub(r"[^0-9a-zA-Z가-힣?.!,¿]+", " ", w)

  w = w.strip()

  # adding a start and an end token to the sentence
  # so that the model know when to start and stop predicting.
  w = '<start> ' + w + ' <end>'
  return w
```

```
en_sentence = u"May I borrow this book?"
sp_sentence = u"¿Puedo tomar prestado este libro?"
print(preprocess_sentence(en_sentence))
print(preprocess_sentence(sp_sentence).encode('utf-8'))
```

```
<start> may i borrow this book ? <end>
b'<start> ₩xc2₩xbf puedo tomar prestado este libro ? <end>'
```

```
# 1. Remove the accents
# 2. Clean the sentences
# 3. Return word pairs in the format: [ENGLISH, SPANISH]
def create_dataset(path, num_examples):
  lines = io.open(path, encoding='UTF-8').read().strip().split('₩n')

  word_pairs = [[preprocess_sentence(w) for w in l.split('₩t')]  for l in lines[:num_examples]]

  return zip(*word_pairs)
```

```
#-*- coding: utf-8 -*-
ko, en = create_dataset(path_to_file, None)
print(en[31999])
print(ko[31999])
```

```
<start> their daily life is full of conversation unlike that of other villagers . <end>
<start> 그들의 생활 속에는 다른 마을의 사람들과 달리 대화 가 매우 많았음을 알 수 있었습니다
```

```
def tokenize(lang):
  lang_tokenizer = tf.keras.preprocessing.text.Tokenizer(
      filters='')
  lang_tokenizer.fit_on_texts(lang)

  tensor = lang_tokenizer.texts_to_sequences(lang)

  tensor = tf.keras.preprocessing.sequence.pad_sequences(tensor,
                                                         padding='post')
```

```
  return tensor, lang_tokenizer

def load_dataset(path, num_examples=None):
  # creating cleaned input, output pairs
  targ_lang, inp_lang = create_dataset(path, num_examples)

  input_tensor, inp_lang_tokenizer = tokenize(inp_lang)
  target_tensor, targ_lang_tokenizer = tokenize(targ_lang)

  return input_tensor, target_tensor, inp_lang_tokenizer, targ_lang_tokenizer
```

Limit the size of the dataset to experiment faster (optional)

Training on the complete dataset of >100,000 sentences will take a long time. To train faster, we can limit the size of the dataset to 30,000 sentences (of course, translation quality degrades with less data):

```
# Try experimenting with the size of that dataset
num_examples = 100000
input_tensor, target_tensor, inp_lang, targ_lang = load_dataset(path_to_file, num_examples)

# Calculate max_length of the target tensors
max_length_targ, max_length_inp = target_tensor.shape[1], input_tensor.shape[1]

print(num_examples, len(input_tensor), len(target_tensor))
```

```
100000 100000 100000
```

```
# Creating training and validation sets using an 80-20 split
input_tensor_train, input_tensor_val, target_tensor_train, target_tensor_val = train_test_split(inp

# Show length
print(len(input_tensor_train), len(target_tensor_train), len(input_tensor_val), len(target_tensor_v
```

```
80000 80000 20000 20000
```

```
def convert(lang, tensor):
  for t in tensor:
    if t!=0:
      print ("%d ----> %s" % (t, lang.index_word[t]))
```

```
print ("Input Language; index to word mapping")
convert(inp_lang, input_tensor_train[0])
print ()
print ("Target Language; index to word mapping")
convert(targ_lang, target_tensor_train[0])
```

```
Input Language; index to word mapping
1 ----> <start>
33 ----> so
```

```
89 ----> did
7 ----> you
2954 ----> load
40 ----> this
128 ----> product
15 ----> ?
2 ----> <end>

Target Language; index to word mapping
1 ----> <start>
32 ----> 그래서
24 ----> 이
427 ----> 제품
77704 ----> 실으셨나요
5 ----> ?
2 ----> <end>
```

```
convert(inp_lang, input_tensor_train[1000])

convert(targ_lang, target_tensor_train[1000])
```

```
1 ----> <start>
77 ----> his
449 ----> words
26 ----> are
414 ----> difficult
6 ----> to
227 ----> understand
3 ----> .
2 ----> <end>
1 ----> <start>
104 ----> 그의
6933 ----> 뜻이
84259 ----> 난해해서
2949 ----> 이해하기
3208 ----> 어려워요
3 ----> .
2 ----> <end>
```

Create a tf.data dataset

```
BUFFER_SIZE = len(input_tensor_train)
BATCH_SIZE = 64
steps_per_epoch = len(input_tensor_train)//BATCH_SIZE
embedding_dim = 256
units = 1024
vocab_inp_size = len(inp_lang.word_index)+1
vocab_tar_size = len(targ_lang.word_index)+1

dataset = tf.data.Dataset.from_tensor_slices((input_tensor_train, target_tensor_train)).shuffle(BUF
dataset = dataset.batch(BATCH_SIZE, drop_remainder=True)

print(vocab_inp_size, vocab_tar_size)
```

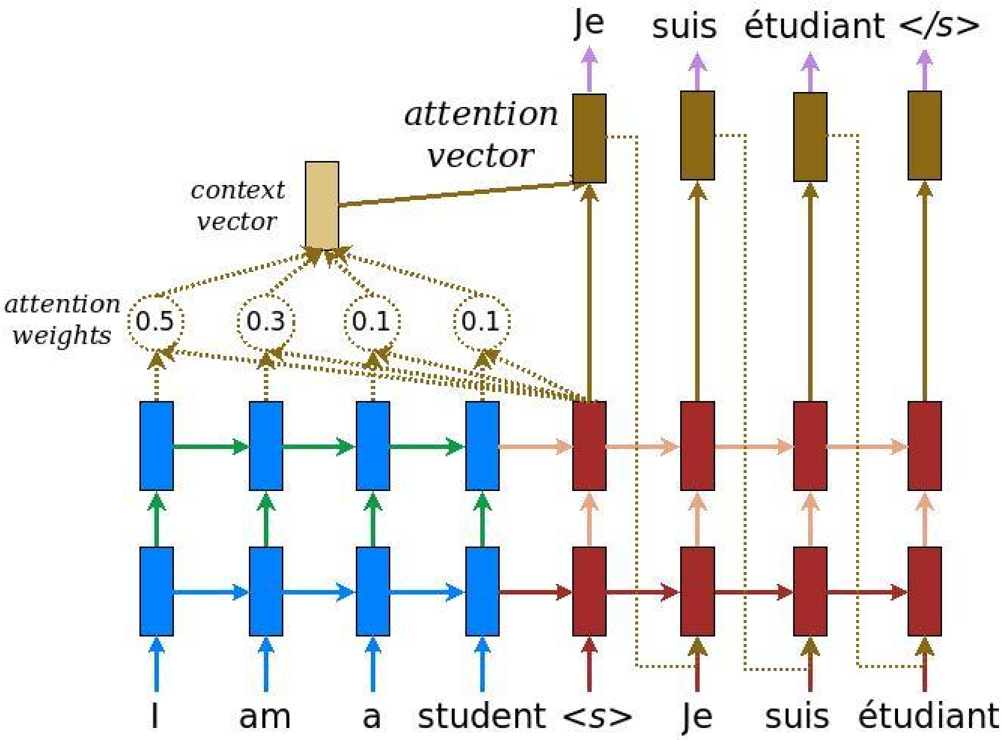
```
26261 121248
```

```
example_input_batch, example_target_batch = next(iter(dataset))
example_input_batch.shape, example_target_batch.shape
```

```
(TensorShape([64, 48]), TensorShape([64, 32]))
```

Write the encoder and decoder model

Implement an encoder-decoder model with attention which you can read about in the TensorFlow [Neural Machine Translation (seq2seq) tutorial](). This example uses a more recent set of APIs. This notebook implements the [attention equations]() from the seq2seq tutorial. The following diagram shows that each input words is assigned a weight by the attention mechanism which is then used by the decoder to predict the next word in the sentence. The below picture and formulas are an example of attention mechanism from [Luong's paper]().



The input is put through an encoder model which gives us the encoder output of shape *(batch_size, max_length, hidden_size)* and the encoder hidden state of shape *(batch_size, hidden_size)*.

Here are the equations that are implemented:

$$
\begin{aligned}
\alpha_{ts} &= \frac{\exp\left(\operatorname{score}(\boldsymbol{h}_t, \bar{\boldsymbol{h}}_s)\right)}{\sum_{s'=1}^{S} \exp\left(\operatorname{score}(\boldsymbol{h}_t, \bar{\boldsymbol{h}}_{s'})\right)} && \text{[Attention weights]} && (1) \\
\boldsymbol{c}_t &= \sum_s \alpha_{ts} \bar{\boldsymbol{h}}_s && \text{[Context vector]} && (2) \\
\boldsymbol{a}_t &= f(\boldsymbol{c}_t, \boldsymbol{h}_t) = \tanh(\boldsymbol{W}_{\boldsymbol{c}}[\boldsymbol{c}_t; \boldsymbol{h}_t]) && \text{[Attention vector]} && (3)
\end{aligned}
$$

$$
\operatorname{score}(\boldsymbol{h}_t, \bar{\boldsymbol{h}}_s) = \begin{cases} \boldsymbol{h}_t^\top \boldsymbol{W} \bar{\boldsymbol{h}}_s & \text{[Luong's multiplicative style]} \\ \boldsymbol{v}_a^\top \tanh\left(\boldsymbol{W}_{\boldsymbol{1}} \boldsymbol{h}_t + \boldsymbol{W}_{\boldsymbol{2}} \bar{\boldsymbol{h}}_s\right) & \text{[Bahdanau's additive style]} \end{cases} \qquad (4)
$$

This tutorial uses Bahdanau attention for the encoder. Let's decide on notation before writing the simplified form:

- FC = Fully connected (dense) layer
- EO = Encoder output
- H = hidden state
- X = input to the decoder

And the pseudo-code:

- `score = FC(tanh(FC(EO) + FC(H)))`
- `attention weights = softmax(score, axis = 1)`. Softmax by default is applied on the last axis but here we want to apply it on the *1st axis*, since the shape of score is *(batch_size, max_length, hidden_size)*. `Max_length` is the length of our input. Since we are trying to assign a weight to each input, softmax should be applied on that axis.
- `context vector = sum(attention weights * EO, axis = 1)`. Same reason as above for choosing axis as 1.
- `embedding output` = The input to the decoder X is passed through an embedding layer.
- `merged vector = concat(embedding output, context vector)`
- This merged vector is then given to the GRU

The shapes of all the vectors at each step have been specified in the comments in the code:

```
class Encoder(tf.keras.Model):
  def __init__(self, vocab_size, embedding_dim, enc_units, batch_sz):
    super(Encoder, self).__init__()
    self.batch_sz = batch_sz
    self.enc_units = enc_units
    self.embedding = tf.keras.layers.Embedding(vocab_size, embedding_dim)
    self.gru = tf.keras.layers.GRU(self.enc_units,
                                   return_sequences=True,
                                   return_state=True,
                                   recurrent_initializer='glorot_uniform')

  def call(self, x, hidden):
    x = self.embedding(x)
```

```
    output, state = self.gru(x, initial_state = hidden)
    return output, state

  def initialize_hidden_state(self):
    return tf.zeros((self.batch_sz, self.enc_units))
```

```
encoder = Encoder(vocab_inp_size, embedding_dim, units, BATCH_SIZE)

# sample input
sample_hidden = encoder.initialize_hidden_state()
sample_output, sample_hidden = encoder(example_input_batch, sample_hidden)
print ('Encoder output shape: (batch size, sequence length, units) {}'.format(sample_output.shape))
print ('Encoder Hidden state shape: (batch size, units) {}'.format(sample_hidden.shape))

encoder.summary()
```

```
Encoder output shape: (batch size, sequence length, units) (64, 48, 1024)
Encoder Hidden state shape: (batch size, units) (64, 1024)
Model: "encoder"
_________________________________________________________________
 Layer (type)                Output Shape              Param #
=================================================================
 embedding (Embedding)       multiple                  6722816

 gru (GRU)                   multiple                  3938304

=================================================================
Total params: 10,661,120
Trainable params: 10,661,120
Non-trainable params: 0
_________________________________________________________________
```

```
class BahdanauAttention(tf.keras.layers.Layer):
  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, query, values):
    # query hidden state shape == (batch_size, hidden size)
    # query_with_time_axis shape == (batch_size, 1, hidden size)
    # values shape == (batch_size, max_len, hidden size)
    # we are doing this to broadcast addition along the time axis to calculate the score
    query_with_time_axis = tf.expand_dims(query, 1)

    # score shape == (batch_size, max_length, 1)
    # we get 1 at the last axis because we are applying score to self.V
    # the shape of the tensor before applying self.V is (batch_size, max_length, units)
    score = self.V(tf.nn.tanh(
        self.W1(query_with_time_axis) + self.W2(values)))

    # attention_weights shape == (batch_size, max_length, 1)
    attention_weights = tf.nn.softmax(score, axis=1)
```

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

    return context_vector, attention_weights
```

```
attention_layer = BahdanauAttention(10)
attention_result, attention_weights = attention_layer(sample_hidden, sample_output)

print("Attention result shape: (batch size, units) {}".format(attention_result.shape))
print("Attention weights shape: (batch_size, sequence_length, 1) {}".format(attention_weights.shape
```

```
Attention result shape: (batch size, units) (64, 1024)
Attention weights shape: (batch_size, sequence_length, 1) (64, 48, 1)
```

```
class Decoder(tf.keras.Model):
  def __init__(self, vocab_size, embedding_dim, dec_units, batch_sz):
    super(Decoder, self).__init__()
    self.batch_sz = batch_sz
    self.dec_units = dec_units
    self.embedding = tf.keras.layers.Embedding(vocab_size, embedding_dim)
    self.gru = tf.keras.layers.GRU(self.dec_units,
                                   return_sequences=True,
                                   return_state=True,
                                   recurrent_initializer='glorot_uniform')
    self.fc = tf.keras.layers.Dense(vocab_size)

    # used for attention
    self.attention = BahdanauAttention(self.dec_units)

  def call(self, x, hidden, enc_output):
    # enc_output shape == (batch_size, max_length, hidden_size)
    context_vector, attention_weights = self.attention(hidden, enc_output)

    # 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)

    # passing the concatenated vector to the GRU
    output, state = self.gru(x)

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

    # output shape == (batch_size, vocab)
    x = self.fc(output)

    return x, state, attention_weights
```

```
decoder = Decoder(vocab_tar_size, embedding_dim, units, BATCH_SIZE)
```

```
sample_decoder_output, _, _ = decoder(tf.random.uniform((BATCH_SIZE, 1)),
                                      sample_hidden, sample_output)

print ('Decoder output shape: (batch_size, vocab size) {}'.format(sample_decoder_output.shape))
decoder.summary()
```

```
Decoder output shape: (batch_size, vocab size) (64, 121248)
Model: "decoder"
_________________________________________________________________
 Layer (type)                Output Shape              Param #   
=================================================================
 embedding_1 (Embedding)     multiple                  31039488  
                                                                 
 gru_1 (GRU)                 multiple                  7084032   
                                                                 
 dense_3 (Dense)             multiple                  124279200 
                                                                 
 bahdanau_attention_1 (Bahda  multiple                 2100225   
 nauAttention)                                                   
                                                                 
=================================================================
Total params: 164,502,945
Trainable params: 164,502,945
Non-trainable params: 0
_________________________________________________________________
```

Define the optimizer and the loss function

```
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_)
```

Checkpoints (Object-based saving)

```
checkpoint_dir = './training_checkpoints'
checkpoint_prefix = os.path.join(checkpoint_dir, "ckpt")
checkpoint = tf.train.Checkpoint(optimizer=optimizer,
                                 encoder=encoder,
                                 decoder=decoder)
```

Training

1. Pass the *input* through the *encoder* which return *encoder output* and the *encoder hidden state*.
2. The encoder output, encoder hidden state and the decoder input (which is the *start token*) is passed to the decoder.
3. The decoder returns the *predictions* and the *decoder hidden state*.
4. The decoder hidden state is then passed back into the model and the predictions are used to calculate the loss.
5. Use *teacher forcing* to decide the next input to the decoder.
6. *Teacher forcing* is the technique where the *target word* is passed as the *next input* to the decoder.
7. The final step is to calculate the gradients and apply it to the optimizer and backpropagate.

```
@tf.function
def train_step(inp, targ, enc_hidden):
  loss = 0

  with tf.GradientTape() as tape:
    enc_output, enc_hidden = encoder(inp, enc_hidden)

    dec_hidden = enc_hidden

    dec_input = tf.expand_dims([targ_lang.word_index['<start>']] * BATCH_SIZE, 1)

    # Teacher forcing - feeding the target as the next input
    for t in range(1, targ.shape[1]):
      # passing enc_output to the decoder
      predictions, dec_hidden, _ = decoder(dec_input, dec_hidden, enc_output)

      loss += loss_function(targ[:, t], predictions)

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

  batch_loss = (loss / int(targ.shape[1]))

  variables = encoder.trainable_variables + decoder.trainable_variables

  gradients = tape.gradient(loss, variables)

  optimizer.apply_gradients(zip(gradients, variables))

  return batch_loss
```

```
EPOCHS = 10

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

```
enc_hidden = encoder.initialize_hidden_state()
total_loss = 0

for (batch, (inp, targ)) in enumerate(dataset.take(steps_per_epoch)):
  batch_loss = train_step(inp, targ, enc_hidden)
  total_loss += batch_loss

  if batch % 100 == 0:
    print('Epoch {} Batch {} Loss {:.4f}'.format(epoch + 1,
                                                 batch,
                                                 batch_loss.numpy()))
# saving (checkpoint) the model every 2 epochs
if (epoch + 1) % 2 == 0:
  checkpoint.save(file_prefix = checkpoint_prefix)

print('Epoch {} Loss {:.4f}'.format(epoch + 1,
                                    total_loss / steps_per_epoch))
print('Time taken for 1 epoch {} sec₩n'.format(time.time() - start))
```

```
        [[node gradient_tape/decoder/dense_3/MatMul_14/MatMul_1
 (defined at <ipython-input-29-49d4266c745b>:26)
]]
Hint: If you want to see a list of allocated tensors when OOM happens, add
report_tensor_allocations_upon_oom to RunOptions for current allocation info. This isn't
available when running in Eager mode.
 [Op:__inference_train_step_58298]

Errors may have originated from an input operation.
Input Source operations connected to node gradient_tape/decoder/dense_3/MatMul_14/MatMul_1:
In[0] decoder/Reshape_14 (defined at <ipython-input-25-94d61fef8257>:30)
In[1]
gradient_tape/sparse_categorical_crossentropy_14/SparseSoftmaxCrossEntropyWithLogits/mul:

Operation defined at: (most recent call last)
>>>   File "/usr/lib/python3.7/runpy.py", line 193, in _run_module_as_main
>>>     "__main__", mod_spec)
>>>
>>>   File "/usr/lib/python3.7/runpy.py", line 85, in _run_code
>>>     exec(code, run_globals)
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/ipykernel_launcher.py", line 16, in
<module>
>>>     app.launch_new_instance()
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/traitlets/config/application.py", line
846, in launch_instance
>>>     app.start()
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/ipykernel/kernelapp.py", line 499, in
start
>>>     self.io_loop.start()
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/tornado/platform/asyncio.py", line 132,
in start
>>>     self.asyncio_loop.run_forever()
>>>
>>>   File "/usr/lib/python3.7/asyncio/base_events.py", line 541, in run_forever
>>>     self._run_once()
>>>
>>>   File "/usr/lib/python3.7/asyncio/base_events.py", line 1786, in _run_once
>>>     handle._run()
>>>
>>>   File "/usr/lib/python3.7/asyncio/events.py", line 88, in _run
>>>     self._context.run(self._callback, *self._args)
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/tornado/ioloop.py", line 758, in
_run_callback
>>>     ret = callback()
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/tornado/stack_context.py", line 300, in
null_wrapper
>>>     return fn(*args, **kwargs)
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/zmq/eventloop/zmqstream.py", line 536, in
<lambda>
>>>     self.io_loop.add_callback(lambda: self._handle_events(self.socket, 0))
```

```
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/zmq/eventloop/zmqstream.py", line 452, in
_handle_events
>>>     self._handle_recv()
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/zmq/eventloop/zmqstream.py", line 481, in
_handle_recv
>>>     self._run_callback(callback, msg)
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/zmq/eventloop/zmqstream.py", line 431, in
_run_callback
>>>     callback(*args, **kwargs)
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/tornado/stack_context.py", line 300, in
null_wrapper
>>>     return fn(*args, **kwargs)
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/ipykernel/kernelbase.py", line 283, in
dispatcher
>>>     return self.dispatch_shell(stream, msg)
>>>
>>>   File "/usr/local/lib/python3.7/dist-packages/ipykernel/kernelbase.py", line 233, in
```

Translate

- The evaluate function is similar to the training loop, except we don't use *teacher forcing* here. The input to the decoder at each time step is its previous predictions along with the hidden state and the encoder output.
- Stop predicting when the model predicts the *end token*.
- And store the *attention weights for every time step*.

Note: The encoder output is calculated only once for one input.

```
def evaluate(sentence):
  attention_plot = np.zeros((max_length_targ, max_length_inp))

  sentence = preprocess_sentence(sentence)

  inputs = [inp_lang.word_index[i] for i in sentence.split(' ')]
  inputs = tf.keras.preprocessing.sequence.pad_sequences([inputs],
                                                         maxlen=max_length_inp,
                                                         padding='post')
  inputs = tf.convert_to_tensor(inputs)

  result = ''

  hidden = [tf.zeros((1, units))]
  enc_out, enc_hidden = encoder(inputs, hidden)

  dec_hidden = enc_hidden
  dec_input = tf.expand_dims([targ_lang.word_index['<start>']], 0)

  for t in range(max_length_targ):
```

```
    predictions, dec_hidden, attention_weights = decoder(dec_input,
                                                         dec_hidden,
                                                         enc_out)

    # storing the attention weights to plot later on
    attention_weights = tf.reshape(attention_weights, (-1, ))
    attention_plot[t] = attention_weights.numpy()

    predicted_id = tf.argmax(predictions[0]).numpy()

    result += targ_lang.index_word[predicted_id] + ' '

    if targ_lang.index_word[predicted_id] == '<end>':
      return result, sentence, attention_plot

    # the predicted ID is fed back into the model
    dec_input = tf.expand_dims([predicted_id], 0)

  return result, sentence, attention_plot
```

```
# function for plotting the attention weights
def plot_attention(attention, sentence, predicted_sentence):
  fig = plt.figure(figsize=(10,10))
  ax = fig.add_subplot(1, 1, 1)
  ax.matshow(attention, cmap='viridis')

  fontdict = {'fontsize': 14}

  ax.set_xticklabels([''] + sentence, fontdict=fontdict, rotation=90)
  ax.set_yticklabels([''] + predicted_sentence, fontdict=fontdict)

  ax.xaxis.set_major_locator(ticker.MultipleLocator(1))
  ax.yaxis.set_major_locator(ticker.MultipleLocator(1))

  plt.show()
```

```
def translate(sentence):
  result, sentence, attention_plot = evaluate(sentence)

  print('Input: %s' % (sentence))
  print('Predicted translation: {}'.format(result))

  attention_plot = attention_plot[:len(result.split(' ')), :len(sentence.split(' '))]
  plot_attention(attention_plot, sentence.split(' '), result.split(' '))
```

Restore the latest checkpoint and test

```
# restoring the latest checkpoint in checkpoint_dir
checkpoint.restore(tf.train.latest_checkpoint(checkpoint_dir))
```

```
---------------------------------------------------------------------------
ValueError                                Traceback (most recent call last)
<ipython-input-34-39e322f5ba03> in <module>()
      1 # restoring the latest checkpoint in checkpoint_dir
----> 2 checkpoint.restore(tf.train.latest_checkpoint(checkpoint_dir))
```

16 frames

```
/usr/local/lib/python3.7/dist-packages/tensorflow/python/framework/tensor_shape.py in
assert_is_compatible_with(self, other)
   1169     """
   1170     if not self.is_compatible_with(other):
-> 1171       raise ValueError("Shapes %s and %s are incompatible" % (self, other))
   1172
   1173   def most_specific_compatible_shape(self, other):

ValueError: Shapes (121248, 256) and (27256, 256) are incompatible
```

```
translate('it is hard to save time')
```

```
Input: <start> it is hard to save time <end>
Predicted translation: 문병을 제작함으로써 지배했던 우편함이 상태예요 교재에 기대되니 아침형
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