Neural Machine Translation with Attention mechanism

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

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

```
!pip install chart-studio
```

```
Looking in indexes: https://pypi.org/simple, https://us-python.pkg.dev/colab-wheels/public/simple/
Collecting chart-studio
  Downloading chart_studio-1.1.0-py3-none-any.whl (64 kB)
     |████████████████████████████████| 64 kB 1.8 MB/s
Collecting retrying>=1.3.3
  Downloading retrying-1.3.4-py3-none-any.whl (11 kB)
Requirement already satisfied: plotly in /usr/local/lib/python3.8/dist-packages (from chart-studio) (5.5.0)
Requirement already satisfied: six in /usr/local/lib/python3.8/dist-packages (from chart-studio) (1.15.0)
Requirement already satisfied: requests in /usr/local/lib/python3.8/dist-packages (from chart-studio) (2.23.0)
Requirement already satisfied: tenacity>=6.2.0 in /usr/local/lib/python3.8/dist-packages (from plotly->chart-studio) (8
Requirement already satisfied: certifi>=2017.4.17 in /usr/local/lib/python3.8/dist-packages (from requests->chart-studi
Requirement already satisfied: chardet<4,>=3.0.2 in /usr/local/lib/python3.8/dist-packages (from requests->chart-studio
Requirement already satisfied: urllib3!=1.25.0,!=1.25.1,<1.26,>=1.21.1 in /usr/local/lib/python3.8/dist-packages (from
Requirement already satisfied: idna<3,>=2.5 in /usr/local/lib/python3.8/dist-packages (from requests->chart-studio) (2.
Installing collected packages: retrying, chart-studio
Successfully installed chart-studio-1.1.0 retrying-1.3.4
```

```
import pandas as pd # data processing, CSV file I/O (e.g. pd.read_csv)
import tensorflow as tf

#tf.enable_eager_execution()

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

import unicodedata
import re
import numpy as np
import time
import string

import chart_studio.plotly
import chart_studio.plotly as py
from plotly.offline import init_notebook_mode, iplot
import plotly.graph_objs as go
```

As in case of any NLP task, after reading the input file, we perform the basic cleaning and preprocessing as follows:

The Dataset : We need a dataset that contains English sentences and their Portuguese translations which can be freely downloaded from this link. Download the file fra-eng.zip and extract it. On each line, the text file contains an English sentence and its French translation, separated by a tab.

```
file_path = '/content/drive/MyDrive/Colab Notebooks/Dataset/hin.txt' # please set the path according to your system
```

```
lines = open(file_path, encoding='UTF-8').read().strip().split('\n')
lines[2000:2010]
```

```
['I was able to play piano very well.\tमैं पियानो बहुत अच्छा बजा लेता था।\tCC-BY 2.0 (France) Attribution: tatoeba.org #28988
(CK) & #505130 (minshirui)',
 'I wish to go to Paris to study art.\tमैं पैरिस जाकर आर्ट पढ़ना चाहता हूँ।\tCC-BY 2.0 (France) Attribution: tatoeba.org #256599
(CK) & #450412 (minshirui)',
 'I wish to go to Paris to study art.\tमैं पैरिस जाकर आर्ट पढ़ना चाहती हूँ।\tCC-BY 2.0 (France) Attribution: tatoeba.org #256599
(CK) & #450413 (minshirui)',
 "I'm anxious for him to return safe.\tमैं उसके सुरक्षित लौटने के लिए बेचैन हूँ।\tCC-BY 2.0 (France) Attribution: tatoeba.org
#284204 (CM) & #505252 (minshirui)",
 "If I don't do it now, I never will.\tअगर मैं अभी नहीं करूँगा तो कभी नहीं करूँगा।\tCC-BY 2.0 (France) Attribution: tatoeba.org
#2193 (CK) & #494208 (minshirui)",
 'If I had wings, I would fly to you.\tअगर मेरे पास पंख होते तो मैं उड़कर तुम्हारे पास चला आता।\tCC-BY 2.0 (France) Attribution:
tatoeba.org #30785 (CM) & #459446 (minshirui)',
 'It has been fine since last Friday.\tपिछले शुक्रवार से मौसम बहुत अच्छा है।\tCC-BY 2.0 (France) Attribution: tatoeba.org #272726
(CK) & #491591 (minshirui)',
 'It is going to rain this afternoon.\tआज दोपहर बारिश होने वाली है।\tCC-BY 2.0 (France) Attribution: tatoeba.org #240067
```

```
     (Zifre) & #487252 (minshirui)',
      'It seems that everybody likes golf.\tऐसा लगता है जैसे कि सभी लोगों को गौल्फ़ अच्छा लगता है।\tCC-BY 2.0 (France) Attribution:
     tatoeba.org #40404 (CK) & #509344 (minshirui)',
      "It shouldn't take long to find Tom.\tटॉम को ढूँढने में समय नहीं लगना चाहिए।\tCC-BY 2.0 (France) Attribution: tatoeba.org
     #3540364 (CK) & #3540404 (nurendra)"]
```

```
print("total number of records: ",len(lines))
```

```
     total number of records:  2909
```

```
exclude = set(string.punctuation) # Set of all special characters
remove_digits = str.maketrans('', '', string.digits) # Set of all digits
```

Function to preprocess English sentence

```
def preprocess_eng_sentence(sent):
    '''Function to preprocess English sentence'''
    sent = sent.lower() # lower casing
    sent = re.sub("'", '', sent) # remove the quotation marks if any
    sent = ''.join(ch for ch in sent if ch not in exclude)
    sent = sent.translate(remove_digits) # remove the digits
    sent = sent.strip()
    sent = re.sub(" +", " ", sent) # remove extra spaces
    sent = '<start> ' + sent + ' <end>' # add <start> and <end> tokens
    return sent
```

Function to preprocess Portuguese sentence

```
def preprocess_port_sentence(sent):
    '''Function to preprocess Portuguese sentence'''
    sent = re.sub("'", '', sent) # remove the quotation marks if any
    sent = ''.join(ch for ch in sent if ch not in exclude)
    #sent = re.sub("[২३০८९५७९४६]", "", sent) # remove the digits
    sent = sent.strip()
    sent = re.sub(" +", " ", sent) # remove extra spaces
    sent = '<start> ' + sent + ' <end>' # add <start> and <end> tokens
    return sent
```

Generate pairs of cleaned English and Portuguese sentences with start and end tokens added.

```
# Generate pairs of cleaned English and Portuguese sentences
sent_pairs = []
for line in lines:
    sent_pair = []
    eng = line.rstrip().split('\t')[0]
    port = line.rstrip().split('\t')[1]
    eng = preprocess_eng_sentence(eng)
    sent_pair.append(eng)
    port = preprocess_port_sentence(port)
    sent_pair.append(port)
    sent_pairs.append(sent_pair)
sent_pairs[5000:5010]
```

```
     []
```

Create a class to map every word to an index and vice-versa for any given vocabulary.

```
# This class creates a word -> index mapping (e.g,. "dad" -> 5) and vice-versa
# (e.g., 5 -> "dad") for each language,
class LanguageIndex():
    def __init__(self, lang):
        self.lang = lang
        self.word2idx = {}
        self.idx2word = {}
        self.vocab = set()

        self.create_index()

    def create_index(self):
        for phrase in self.lang:
            self.vocab.update(phrase.split(' '))
```

```
        self.vocab = sorted(self.vocab)

        self.word2idx['<pad>'] = 0
        for index, word in enumerate(self.vocab):
            self.word2idx[word] = index + 1

        for word, index in self.word2idx.items():
            self.idx2word[index] = word

def max_length(tensor):
    return max(len(t) for t in tensor)
```

Tokenization and Padding

```
def load_dataset(pairs, num_examples):
    # pairs => already created cleaned input, output pairs

    # index language using the class defined above
    inp_lang = LanguageIndex(en for en, ma in pairs)
    targ_lang = LanguageIndex(ma for en, ma in pairs)

    # Vectorize the input and target languages

    # English sentences
    input_tensor = [[inp_lang.word2idx[s] for s in en.split(' ')] for en, ma in pairs]

    # Marathi sentences
    target_tensor = [[targ_lang.word2idx[s] for s in ma.split(' ')] for en, ma in pairs]

    # Calculate max_length of input and output tensor
    # Here, we'll set those to the longest sentence in the dataset
    max_length_inp, max_length_tar = max_length(input_tensor), max_length(target_tensor)

    # Padding the input and output tensor to the maximum length
    input_tensor = tf.keras.preprocessing.sequence.pad_sequences(input_tensor,
                                                                 maxlen=max_length_inp,
                                                                 padding='post')

    target_tensor = tf.keras.preprocessing.sequence.pad_sequences(target_tensor,
                                                                  maxlen=max_length_tar,
                                                                  padding='post')

    return input_tensor, target_tensor, inp_lang, targ_lang, max_length_inp, max_length_tar


input_tensor, target_tensor, inp_lang, targ_lang, max_length_inp, max_length_targ = load_dataset(sent_pairs, len(lines))
```

Creating training and validation sets using an 80-20 split

```
# 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(input_tensor, target_tensor,

# Show length
len(input_tensor_train), len(target_tensor_train), len(input_tensor_val), len(target_tensor_val)
```

```
     (2618, 2618, 291, 291)
```

```
BUFFER_SIZE = len(input_tensor_train)
BATCH_SIZE = 64
N_BATCH = BUFFER_SIZE//BATCH_SIZE
embedding_dim = 256
units = 1024
vocab_inp_size = len(inp_lang.word2idx)
vocab_tar_size = len(targ_lang.word2idx)

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

We'll be using GRUs instead of LSTMs as we only have to create one state and implementation would be easier.

Create GRU units

```
def gru(units):
```

```
    return tf.keras.layers.GRU(units,
                                return_sequences=True,
                                return_state=True,
                                recurrent_activation='sigmoid',
                                recurrent_initializer='glorot_uniform')
```

The next step is to define the encoder and decoder network.

The input to the encoder will be the sentence in English and the output will be the hidden state and cell state of the GRU.

```
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 = gru(self.enc_units)

    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))
```

The next step is to define the decoder. The decoder will have two inputs: the hidden state and cell state from the encoder and the input sentence, which actually will be the output sentence with a token appended at the beginning.

```
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 = gru(self.dec_units)
        self.fc = tf.keras.layers.Dense(vocab_size)

        # used for attention
        self.W1 = tf.keras.layers.Dense(self.dec_units)
        self.W2 = tf.keras.layers.Dense(self.dec_units)
        self.V = tf.keras.layers.Dense(1)

    def call(self, x, hidden, enc_output):

        hidden_with_time_axis = tf.expand_dims(hidden, 1)

        # score shape == (batch_size, max_length, 1)
        # we get 1 at the last axis because we are applying tanh(FC(EO) + FC(H)) to self.V
        score = self.V(tf.nn.tanh(self.W1(enc_output) + self.W2(hidden_with_time_axis)))

        # 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 * enc_output
        context_vector = tf.reduce_sum(context_vector, axis=1)

        # 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 * 1, vocab)
        x = self.fc(output)

        return x, state, attention_weights

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

Create encoder and decoder objects from their respective classes.

```
encoder = Encoder(vocab_inp_size, embedding_dim, units, BATCH_SIZE)
decoder = Decoder(vocab_tar_size, embedding_dim, units, BATCH_SIZE)
```

Define the optimizer and the loss function.

```
optimizer = tf.optimizers.Adam()

def loss_function(real, pred):
    mask = 1 - np.equal(real, 0)
    loss_ = tf.nn.sparse_softmax_cross_entropy_with_logits(labels=real, logits=pred) * mask
    return tf.reduce_mean(loss_)


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

Training the Model

```
EPOCHS = 10

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

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

    for (batch, (inp, targ)) in enumerate(dataset):
        loss = 0

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

            dec_hidden = enc_hidden

            dec_input = tf.expand_dims([targ_lang.word2idx['<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]))

        total_loss += batch_loss

        variables = encoder.variables + decoder.variables

        gradients = tape.gradient(loss, variables)

        optimizer.apply_gradients(zip(gradients, variables))

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

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

```
Epoch 1 Batch 0 Loss 2.3151
Epoch 1 Loss 1.8955
Time taken for 1 epoch 562.6970763206482 sec

Epoch 2 Batch 0 Loss 1.5634
Epoch 2 Loss 1.6400
Time taken for 1 epoch 517.2413923740387 sec

Epoch 3 Batch 0 Loss 1.4227
Epoch 3 Loss 1.5324
Time taken for 1 epoch 562.6500766277313 sec

Epoch 4 Batch 0 Loss 1.3861
Epoch 4 Loss 1.4374
Time taken for 1 epoch 562.61279296875 sec

Epoch 5 Batch 0 Loss 1.3500
Epoch 5 Loss 1.3638
Time taken for 1 epoch 562.6867008209229 sec

Epoch 6 Batch 0 Loss 1.3561
Epoch 6 Loss 1.2947
Time taken for 1 epoch 510.52578949928284 sec

Epoch 7 Batch 0 Loss 1.2333
Epoch 7 Loss 1.2191
Time taken for 1 epoch 562.73872590065 sec

Epoch 8 Batch 0 Loss 1.2444
Epoch 8 Loss 1.1517
Time taken for 1 epoch 513.6766695976257 sec

Epoch 9 Batch 0 Loss 1.1008
Epoch 9 Loss 1.0735
Time taken for 1 epoch 562.7210397720337 sec

Epoch 10 Batch 0 Loss 0.9668
Epoch 10 Loss 1.0012
Time taken for 1 epoch 562.5892231464386 sec
```

Restoring the latest checkpoint

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

```
<tensorflow.python.training.tracking.util.InitializationOnlyStatus at 0x7fe94f3a5f40>
```

Inference setup and testing:

```
def evaluate(inputs, encoder, decoder, inp_lang, targ_lang, max_length_inp, max_length_targ):

    attention_plot = np.zeros((max_length_targ, max_length_inp))
    sentence = ''
    for i in inputs[0]:
        if i == 0:
            break
        sentence = sentence + inp_lang.idx2word[i] + ' '
    sentence = sentence[:-1]

    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.word2idx['<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.idx2word[predicted_id] + ' '

        if targ_lang.idx2word[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 to predict (translate) a randomly selected test point

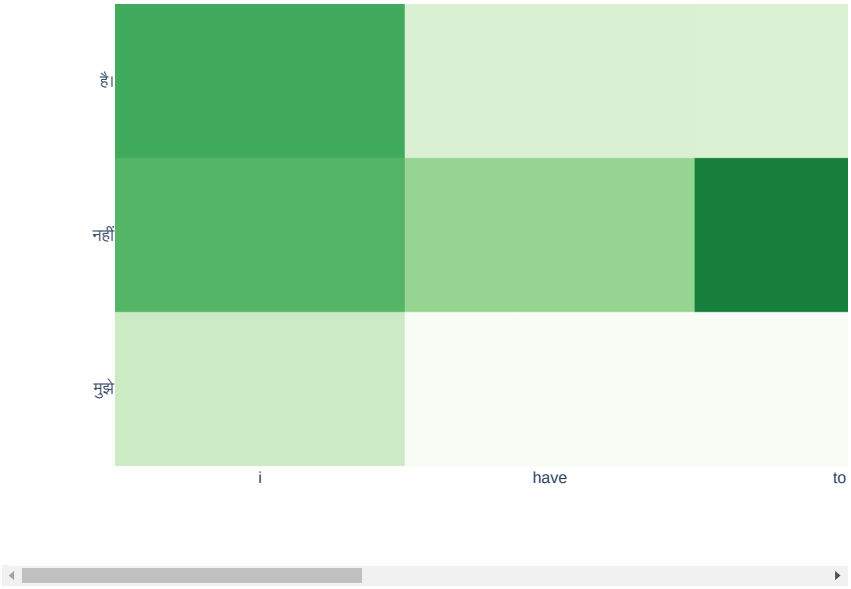
```
def predict_random_val_sentence():
    actual_sent = ''
    k = np.random.randint(len(input_tensor_val))
    random_input = input_tensor_val[k]
    random_output = target_tensor_val[k]
    random_input = np.expand_dims(random_input,0)
    result, sentence, attention_plot = evaluate(random_input, encoder, decoder, inp_lang, targ_lang, max_length_inp, max_len
    print('Input: {}'.format(sentence[8:-6]))
    print('Predicted translation: {}'.format(result[:-6]))
    for i in random_output:
        if i == 0:
            break
        actual_sent = actual_sent + targ_lang.idx2word[i] + ' '
    actual_sent = actual_sent[8:-7]
    print('Actual translation: {}'.format(actual_sent))
    attention_plot = attention_plot[:len(result.split(' '))-2, 1:len(sentence.split(' '))-1]
    sentence, result = sentence.split(' '), result.split(' ')
    sentence = sentence[1:-1]
    result = result[:-2]

    # use plotly to generate the heat map
    trace = go.Heatmap(z = attention_plot, x = sentence, y = result, colorscale='greens')
    data=[trace]
```

```
    iplot(data)
```

```
predict_random_val_sentence()
```

```
     Input: i have to answer his letter
     Predicted translation: मुझे नहीं है।
     Actual translation: मुझे उसकी चिट्ठी का जवाब देना है।
```




```
predict_random_val_sentence()
```

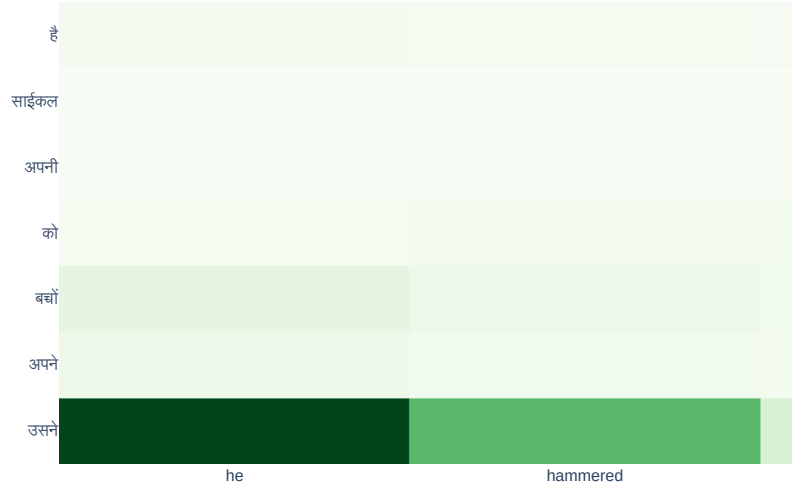
```
     Input: dont ask me for money
     Predicted translation: मुझे नहीं है।
     Actual translation: मुझसे पैसे मत माँगो।
```


```
predict_random_val_sentence()
```

```
Input: it will snow tomorrow
Predicted translation: मुझे अपनी साईकल है
Actual translation: कल बरफ़ पड़ेगी।
```


```
predict_random_val_sentence()
```

```
Input: he hammered at the window
Predicted translation: उसने अपने बच्चों को अपनी साईकल है
Actual translation: उसने खिड़की पर ज़ोर लगाकर खटखटाया।
```




```
predict_random_val_sentence()
```

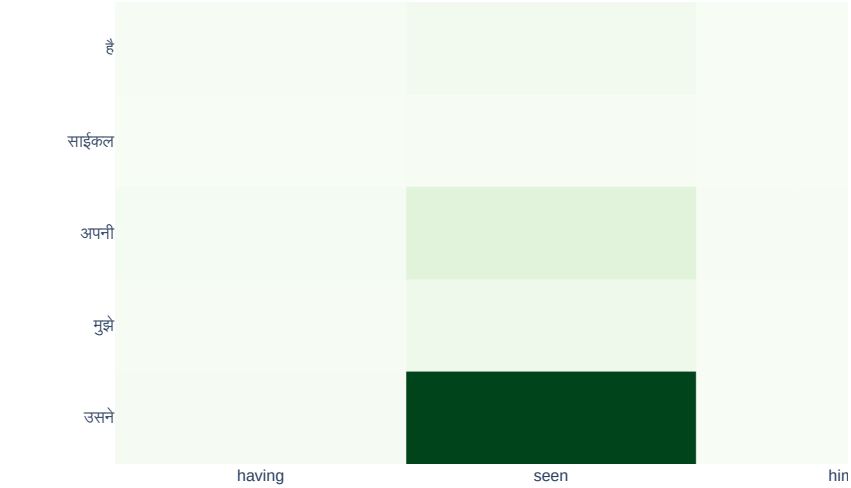
```
Input: maybe im unhappy but i dont intend to kill myself
Predicted translation: मुझे नहीं पता।
Actual translation: हाँ शायद मैं दुखी हूँ पर मुझे अपनी जान लेने का इरादा नहीं है।
```

```
predict_random_val_sentence()
```

```
Input: there were two murders this month
Predicted translation: वह अपने बच्चों को अपनी साईकल पर बहुत देर से पहले एक बार जाने का मन
Actual translation: इस महीने दो हत्याएँ हुई हैं।
```


```
predict_random_val_sentence()
```

```
Input: having seen him before i recognized him
Predicted translation: उसने मुझे अपनी साईकल है
Actual translation: मैंने उसे पहले देखा हुआ था इसलिए मैंने उसे पहचान लिया।
```




```
predict_random_val_sentence()
```

Input: use_big_story true

1h 20m 33s completed at 13:16