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Draft Session (10m)

[1]:

```
import pandas as pd
import numpy as np
import string
from string import digits
import matplotlib.pyplot as plt
import seaborn as sns
import re
from sklearn.model_selection import train_test_split
import tensorflow as tf
from keras.layers import Input, LSTM, Embedding, Dense, Bidirectional, Concatenate, Dot, Activation, TimeDistributed
from keras.models import Model
from keras.utils import plot_model
```

[2]:

```
data_path = "/kaggle/input/simple-dialogs-for-chatbot/dialogs.txt"
```

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Draft Session (12m)

[3]:

```
with open(data_path, 'r', encoding='utf-8') as f:
    lines = f.read().split('\n')
inputs = []
targets = []
num_samples = 10000  # Number of samples to train on.
for line in lines[: min(num_samples, len(lines) - 1)]:

  input, target = line.split('\t')
  inputs.append(input)
  targets.append(target)
```

+ Code + Markdown

[4]:

```
lines = pd.DataFrame({'input':inputs, 'target':targets})
```

[5]:

```
lines.shape
```

[5]: (3724, 2)

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Cancel Run Code Draft Session (13m)

[6]:

```
lines.head()
```

[6]:

	input	target
0	hi, how are you doing?	i'm fine. how about yourself?
1	i'm fine. how about yourself?	i'm pretty good. thanks for asking.
2	i'm pretty good. thanks for asking.	no problem. so how have you been?
3	no problem. so how have you been?	i've been great. what about you?
4	i've been great. what about you?	i've been good. i'm in school right now.

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[7]:

```
def cleanup(lines):
  # Since we work on word level, if we normalize the text to lower case, this will reduce the vocabulary. It's easy to recover the case later.
  lines.input=lines.input.apply(lambda x: x.lower())
  lines.target=lines.target.apply(lambda x: x.lower())

  # To help the model capture the word separations, mark the comma with special token:
  lines.input=lines.input.apply(lambda x: re.sub("'", '', x)).apply(lambda x: re.sub(",", ' COMMA', x))
  lines.target=lines.target.apply(lambda x: re.sub("'", '', x)).apply(lambda x: re.sub(",", ' COMMA', x))

  # Clean up punctuations and digits. Such special chars are common to both domains, and can just be copied with no error.
  exclude = set(string.punctuation)
  lines.input=lines.input.apply(lambda x: ''.join(ch for ch in x if ch not in exclude))
  lines.target=lines.target.apply(lambda x: ''.join(ch for ch in x if ch not in exclude))

  remove_digits = str.maketrans('', '', digits)
  lines.input=lines.input.apply(lambda x: x.translate(remove_digits))
  lines.target=lines.target.apply(lambda x: x.translate(remove_digits))
```

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Draft Session (14m)

[8]:

```
st_tok = 'START_'
end_tok = '_END'
def data_prep(lines):
  cleanup(lines)
  lines.target = lines.target.apply(lambda x : st_tok + ' ' + x + ' ' + end_tok)
```

[9]:

```
data_prep(lines)
```

[10]:

```
lines.head()
```

[10]:

	input	target
0	hi COMMA how are you doing	START_ im fine how about yourself _END
1	im fine how about yourself	START_ im pretty good thanks for asking _END
2	im pretty good thanks for asking	START_ no problem so how have you been _END
3	no problem so how have you been	START_ ive been great what about you _END
4	ive been great what about you	START_ ive been good im in school right now _END

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Draft Session (15m)

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[11]:

```
def tok_split_word2word(data):
  return data.split()
```

[12]:

```
tok_split_fn = tok_split_word2word
```

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Cancel Run Code Draft Session (16m)

[13]:

```
def data_stats(lines, input_tok_split_fn, target_tok_split_fn):
  input_tokens=set()
  for line in lines.input:
      for tok in input_tok_split_fn(line):
          if tok not in input_tokens:
              input_tokens.add(tok)

  target_tokens=set()
  for line in lines.target:
      for tok in target_tok_split_fn(line):
          if tok not in target_tokens:
              target_tokens.add(tok)
  input_tokens = sorted(list(input_tokens))
  target_tokens = sorted(list(target_tokens))

  num_encoder_tokens = len(input_tokens)
  num_decoder_tokens = len(target_tokens)
  max_encoder_seq_length = np.max([len(input_tok_split_fn(l)) for l in lines.input])
  max_decoder_seq_length = np.max([len(target_tok_split_fn(l)) for l in lines.target])

  return input_tokens, target_tokens, num_encoder_tokens, num_decoder_tokens, max_encoder_seq_length, max_decoder_seq_length
```

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Cancel Run Code Draft Session (17m)

[14]:

```
input_tokens, target_tokens, num_encoder_tokens, num_decoder_tokens, max_encoder_seq_length, max_decoder_seq_length = data_stats(lines, input_t
print('Number of samples:', len(lines))
print('Number of unique input tokens:', num_encoder_tokens)
print('Number of unique output tokens:', num_decoder_tokens)
print('Max sequence length for inputs:', max_encoder_seq_length)
print('Max sequence length for outputs:', max_decoder_seq_length)
```

```
Number of samples: 3724
Number of unique input tokens: 2338
Number of unique output tokens: 2400
Max sequence length for inputs: 20
Max sequence length for outputs: 22
```

[15]:

```
pad_tok = 'PAD'
sep_tok = ' '
special_tokens = [pad_tok, sep_tok, st_tok, end_tok]
num_encoder_tokens += len(special_tokens)
num_decoder_tokens += len(special_tokens)
```

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Cancel Run Code Draft Session (18m)

[16]:

```
def vocab(input_tokens, target_tokens):

  input_token_index = {}
  target_token_index = {}
  for i,tok in enumerate(special_tokens):
    input_token_index[tok] = i
    target_token_index[tok] = i

  offset = len(special_tokens)
  for i, tok in enumerate(input_tokens):
    input_token_index[tok] = i+offset

  for i, tok in enumerate(target_tokens):
    target_token_index[tok] = i+offset

  # Reverse-lookup token index to decode sequences back to something readable.
  reverse_input_tok_index = dict(
      (i, tok) for tok, i in input_token_index.items())
  reverse_target_tok_index = dict(
      (i, tok) for tok, i in target_token_index.items())
  return input_token_index, target_token_index, reverse_input_tok_index, reverse_target_tok_index
```

[17]:
```
input_token_index, target_token_index, reverse_input_tok_index, reverse_target_tok_index = vocab(input_tokens, target_tokens)
```

+ Code + Markdown

[18]:
```
max_encoder_seq_length = 30
max_decoder_seq_length = 30
```

[19]:
```
def init_model_inputs(lines, max_encoder_seq_length, max_decoder_seq_length, num_decoder_tokens):
  encoder_input_data = np.zeros(
      (len(lines.input), max_encoder_seq_length),
      dtype='float32')
  decoder_input_data = np.zeros(
      (len(lines.target), max_decoder_seq_length),
      dtype='float32')
  decoder_target_data = np.zeros(
      (len(lines.target), max_decoder_seq_length, num_decoder_tokens),
      dtype='float32')

  return encoder_input_data, decoder_input_data, decoder_target_data
```

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[20]:
```
def vectorize(lines, max_encoder_seq_length, max_decoder_seq_length, num_decoder_tokens, input_tok_split_fn, target_tok_split_fn):
  encoder_input_data, decoder_input_data, decoder_target_data = init_model_inputs(lines, max_encoder_seq_length, max_decoder_seq_length, num_de
  for i, (input_text, target_text) in enumerate(zip(lines.input, lines.target)):
      for t, tok in enumerate(input_tok_split_fn(input_text)):
          encoder_input_data[i, t] = input_token_index[tok]
      encoder_input_data[i, t+1:] = input_token_index[pad_tok]
      for t, tok in enumerate(target_tok_split_fn(target_text)):
          # decoder_target_data is ahead of decoder_input_data by one timestep
          decoder_input_data[i, t] = target_token_index[tok]
          if t > 0:
              # decoder_target_data will be ahead by one timestep
              # and will not include the start character.
              decoder_target_data[i, t - 1, target_token_index[tok]] = 1.
      decoder_input_data[i, t+1:] = target_token_index[pad_tok]
      decoder_target_data[i, t:, target_token_index[pad_tok]] = 1.

  return encoder_input_data, decoder_input_data, decoder_target_data
```

[21]:
```
encoder_input_data, decoder_input_data, decoder_target_data  = vectorize(lines, max_encoder_seq_length, max_decoder_seq_length, num_decoder_tok
```

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Run All Code Draft Session (48m)

[22]:

```python
def seq2seq_attention(num_encoder_tokens, num_decoder_tokens, emb_sz, latent_dim):
    # Define an input sequence and process it.
    encoder_inputs = Input(shape=(None,), dtype='float32')
    encoder_inputs_ = Embedding(num_encoder_tokens, emb_sz, mask_zero=True)(encoder_inputs)

    encoder = Bidirectional(LSTM(latent_dim, return_state=True, return_sequences=True)) # Bi LSTM
    encoder_outputs, state_f_h, state_f_c, state_b_h, state_b_c = encoder(encoder_inputs_)# Bi LSTM
    state_h = Concatenate()([state_f_h, state_b_h])# Bi LSTM
    state_c = Concatenate()([state_f_c, state_b_c])# Bi LSTM

    # We discard `encoder_outputs` and only keep the states.
    encoder_states = [state_h, state_c]# Bi GRU, LSTM, BHi LSTM
    print(encoder_states)

    decoder_inputs = Input(shape=(None,))
    decoder_inputs_ = Embedding(num_decoder_tokens, emb_sz, mask_zero=True)(decoder_inputs)
    # We set up our decoder to return full output sequences,
    # and to return internal states as well. We don't use the
    # return states in the training model, but we will use them in inference.
    decoder_lstm = LSTM(latent_dim*2, return_sequences=True, return_state=True)# Bi LSTM

    decoder_outputs, _, _ = decoder_lstm(decoder_inputs_, initial_state=encoder_states)

    # Equation (7) with 'dot' score from Section 3.1 in the paper.
    # Note that we reuse Softmax-activation layer instead of writing tensor calculation
    print(decoder_outputs)
```

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Run All Code Draft Session (51m)

```python
    # Note that we reuse Softmax-activation layer instead of writing tensor calculation
    print(decoder_outputs)
    print(encoder_outputs)
    att_dot = Dot(axes=[2, 2])
    attention = att_dot([decoder_outputs, encoder_outputs])
    att_activation = Activation('softmax', name='attention')
    attention = att_activation(attention)
    print('attention', attention)
    context_dot = Dot(axes=[2,1])
    context = context_dot([attention, encoder_outputs])
    att_context_concat = Concatenate()
    decoder_combined_context = att_context_concat([context, decoder_outputs])

    # Has another weight + tanh layer as described in equation (5) of the paper

    decoder_dense = Dense(num_decoder_tokens, activation='softmax')
    #decoder_outputs = decoder_dense(decoder_outputs)
    decoder_outputs = decoder_dense(decoder_combined_context)

    # Define the model that will turn
    # `encoder_input_data` & `decoder_input_data` into `decoder_target_data`
    model = Model([encoder_inputs, decoder_inputs], decoder_outputs)

    model.compile(optimizer=tf.keras.optimizers.Adam(lr = 0.00001), loss='categorical_crossentropy', metrics=['acc'])

    print('encoder-decoder  model:')
    print(model.summary())
```

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Run All Code Draft Session (57m)

```python
    print(encoder_inputs)
    print(encoder_outputs)
    print(encoder_states)
    encoder_model = Model(encoder_inputs, [encoder_outputs] + encoder_states)

    decoder_encoder_inputs = Input(shape=(None, latent_dim*2,))
    decoder_state_input_h = Input(shape=(latent_dim*2,))# Bi LSTM
    decoder_state_input_c = Input(shape=(latent_dim*2,)) # Bi LSTM
    decoder_states_inputs = [decoder_state_input_h, decoder_state_input_c]
    decoder_outputs, state_h, state_c = decoder_lstm(decoder_inputs_, initial_state=decoder_states_inputs)
    decoder_states = [state_h, state_c]
    attention = att_dot([decoder_outputs, decoder_encoder_inputs])
    attention = att_activation(attention)
    context = context_dot([attention, decoder_encoder_inputs])
    decoder_combined_context = att_context_concat([context, decoder_outputs])
    decoder_outputs = decoder_dense(decoder_combined_context)
    decoder_model = Model(
        [decoder_inputs, decoder_encoder_inputs] + decoder_states_inputs,
        [decoder_outputs, attention] + decoder_states)
    return model, encoder_model, decoder_model
```

+ Code + Markdown

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Run All Code

Draft Session (59m)

[23]:

```
emb_sz = 20
```

[24]:

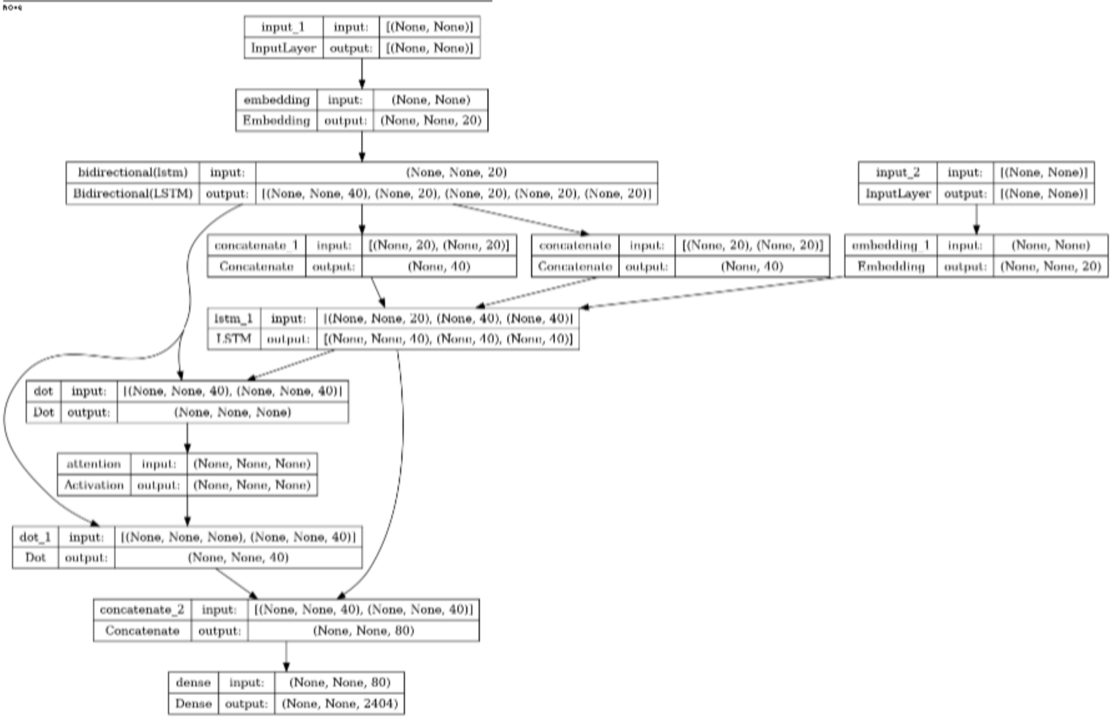
```
model, encoder_model, decoder_model = seq2seq_attention(num_encoder_tokens, num_decoder_tokens, emb_sz=emb_sz, latent_dim=emb_sz)
print(model.summary())
plot_model(model, show_shapes=True, show_layer_names=True)
```

```
[<KerasTensor: shape=(None, 40) dtype=float32 (created by layer 'concatenate')>, <KerasTensor: shape=(None, 40) dtype=float32 (created by layer 'concatenate_1')>]
KerasTensor(type_spec=TensorSpec(shape=(None, None, 40), dtype=tf.float32, name=None), name='lstm_1/PartitionedCall:1', description="created by layer 'lstm_1'")
KerasTensor(type_spec=TensorSpec(shape=(None, None, 40), dtype=tf.float32, name=None), name='bidirectional/concat:0', description="created by layer 'bidirectional'")
attention KerasTensor(type_spec=TensorSpec(shape=(None, None, None), dtype=tf.float32, name=None), name='attention/Softmax:0', description="created by layer 'attenti
on'")
encoder-decoder  model:
Model: "model"
__________________________________________________________________________________________________
 Layer (type)                   Output Shape         Param #     Connected to
==================================================================================================
 input_1 (InputLayer)           [(None, None)]       0           []

 embedding (Embedding)          (None, None, 20)     46840       ['input_1[0][0]']

 input_2 (InputLayer)           [(None, None)]       0           []

 bidirectional (Bidirectional)  [(None, None, 40),   6560        ['embedding[0][0]']
                                 (None, 20),
                                 (None, 20),
                                 (None, 20),
                                 (None, 20)]
```



+ Code   + Markdown

[25]:

```
model.fit([encoder_input_data, decoder_input_data], decoder_target_data,
          batch_size=32,
          epochs=100)
```

```
Epoch 1/100
117/117 [==============================] - 28s 105ms/step - loss: 6.3678 - acc: 0.1245
Epoch 2/100
117/117 [==============================] - 12s 106ms/step - loss: 5.2753 - acc: 0.1241
Epoch 3/100
117/117 [==============================] - 12s 103ms/step - loss: 5.0216 - acc: 0.1708
Epoch 4/100
117/117 [==============================] - 12s 107ms/step - loss: 4.8021 - acc: 0.2277
Epoch 5/100
117/117 [==============================] - 13s 108ms/step - loss: 4.6844 - acc: 0.2441
Epoch 6/100
117/117 [==============================] - 12s 106ms/step - loss: 4.6001 - acc: 0.2549
Epoch 7/100
117/117 [==============================] - 13s 107ms/step - loss: 4.5283 - acc: 0.2603
Epoch 8/100
117/117 [==============================] - 12s 105ms/step - loss: 4.4614 - acc: 0.2659
Epoch 9/100
117/117 [==============================] - 12s 107ms/step - loss: 4.4039 - acc: 0.2705
```

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Run All   Code   Draft Session (1h:3m)

[26]:

```
def decode_sequence_attention(input_seq, sep=' '):
    # Encode the input as state vectors.
    encoder_outputs, h, c = encoder_model.predict(input_seq)
    states_value = [h,c]
    # Generate empty target sequence of length 1.
    target_seq = np.zeros((1,1))
    # Populate the first character of target sequence with the start character.
    target_seq[0, 0] = target_token_index[st_tok]
    # Sampling loop for a batch of sequences
    # (to simplify, here we assume a batch of size 1).
    stop_condition = False
    decoded_sentence = ''
    attention_density = []
    while not stop_condition:
        output_tokens, attention, h, c  = decoder_model.predict(
            [target_seq, encoder_outputs] + states_value)
        attention_density.append(attention[0][0])# attention is max_sent_len x 1 since we have num_time_steps = 1 for the output
        # Sample a token
        sampled_token_index = np.argmax(output_tokens[0, -1, :])
        sampled_tok = reverse_target_tok_index[sampled_token_index]
        decoded_sentence += sep + sampled_tok
        if (sampled_tok == end_tok or
           len(decoded_sentence) > 52):
            stop_condition = True

        # Update the target sequence (of length 1).
        target_seq = np.zeros((1,1))
        target_seq[0, 0] = sampled_token_index

        # Update states
        states_value = [h, c]
    attention_density = np.array(attention_density)
    return decoded_sentence, attention_density
```

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Run All Code Draft Session (1h:5m)

[27]:
```
lines.input[0]
```

[27]: 'hi COMMA how are you doing'

[28]:
```
word_decoded_sents = []
for seq_index in range(100): #[14077,20122,40035,40064, 40056, 40068, 40090, 40095, 40100, 40119, 40131, 40136, 40150, 40153]:
    input_seq = encoder_input_data[seq_index: seq_index + 1]
    decoded_sentence, attention = decode_sequence_attention(input_seq)
    print('-')
    print('Input sentence:', lines.input[seq_index: seq_index + 1])
    print('Decoded sentence:', decoded_sentence)
    word_decoded_sents.append(decoded_sentence)
```

```
1/1 [==============================] - 3s 3s/step
1/1 [==============================] - 2s 2s/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 32ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 33ms/step
-
Input sentence: 0    hi COMMA how are you doing
Name: input, dtype: object
Decoded sentence:  i havent told me the car _END
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 28ms/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 31ms/step
1/1 [==============================] - 0s 29ms/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 27ms/step
1/1 [==============================] - 0s 30ms/step
1/1 [==============================] - 0s 28ms/step
```

[29]:
```
def calculate_WER_sent(gt, pred):
    '''
    calculate_WER('calculating wer between two sentences', 'calculate wer between two sentences')
    '''
    gt_words = gt.lower().split(' ')
    pred_words = pred.lower().split(' ')
    d = np.zeros(((len(gt_words) + 1), (len(pred_words) + 1)), dtype=np.uint8)
    for i in range(len(gt_words) + 1):
        for j in range(len(pred_words) + 1):
            if i == 0:
                d[0][j] = j
            elif j == 0:
                d[i][0] = i
    for i in range(1, len(gt_words) + 1):
        for j in range(1, len(pred_words) + 1):
            if gt_words[i - 1] == pred_words[j - 1]:
                d[i][j] = d[i - 1][j - 1]
            else:
                substitution = d[i - 1][j - 1] + 1
                insertion = d[i][j - 1] + 1
                deletion = d[i - 1][j] + 1
                d[i][j] = min(substitution, insertion, deletion)
    return d[len(gt_words)][len(pred_words)]
def calculate_WER(gt, pred):
    '''

    :param gt: list of sentences of the ground truth
    :param pred: list of sentences of the predictions
    both lists must have the same length
    :return: accumulated WER
    '''
    WER = 0
    nb_w = 0
    for i in range(len(gt)):
        #print(gt[i])
        #print(pred[i])
        WER += calculate_WER_sent(gt[i], pred[i])
        nb_w += len(gt[i])
    return WER / nb_w
```

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Run All Code

Draft Session (1h:8m)

```
    return WER / nb_w
```

[30]:

```
target_sents = list(lines.target[:100])
target_sents = [x[1:-1] for x in target_sents]
word_decoded_sents = [' '.join(x.split()[1:-1]) for x in word_decoded_sents]
```

[31]:

```
WER_word = calculate_WER(target_sents, word_decoded_sents)
print('Word level NMT WER = ', str(WER_word))
```

```
Word level NMT WER =  0.19168962350780533
```