

POS Tagging: Viterbi Algorithm and Deep Learning Comparision

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Task 1:

Part 1:

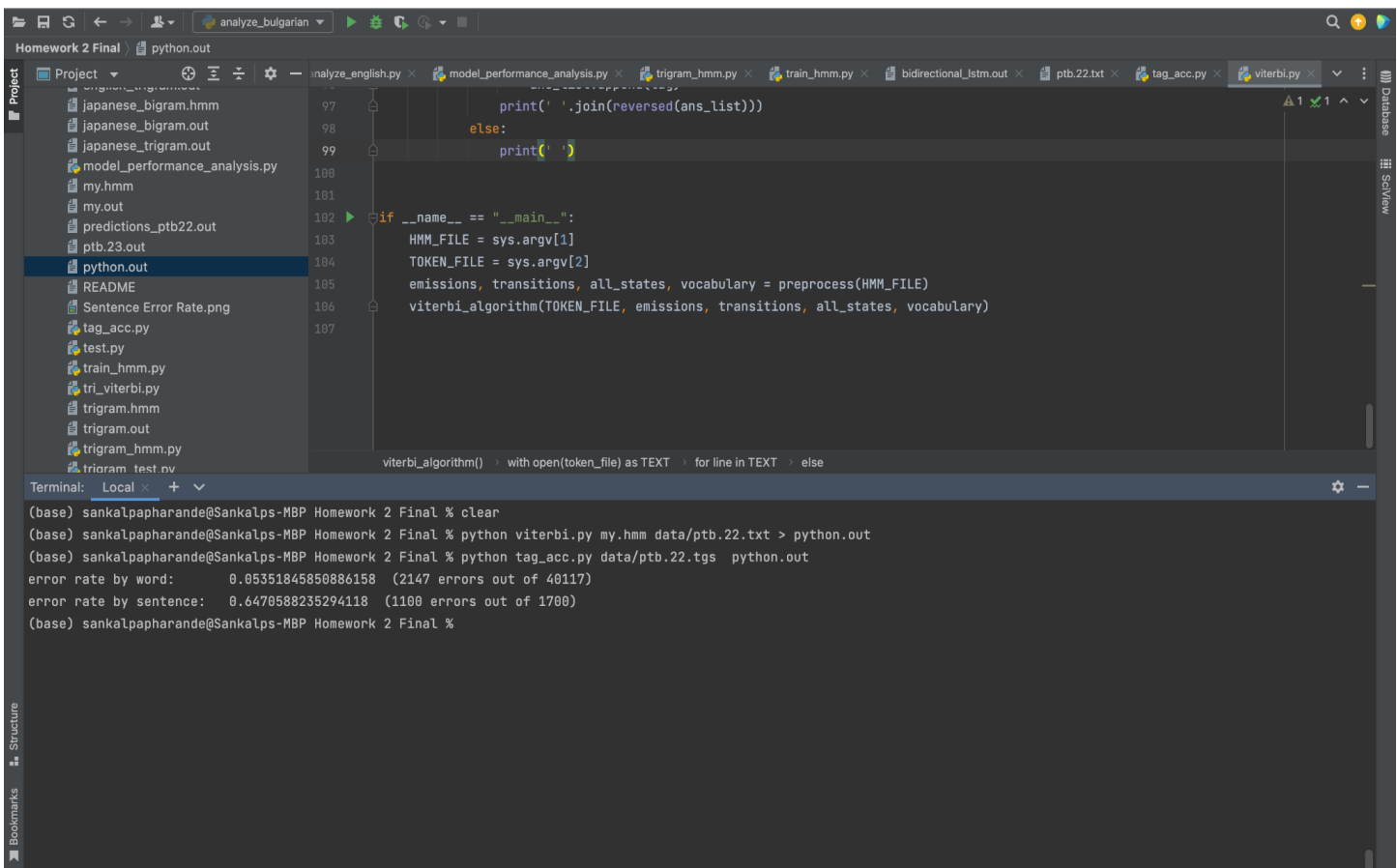
Viterbi.py contains the Viterbi algorithm for POS Tagging using Bigrams in Python.

Results on the output of the Viterbi python algorithm

error rate by word: 0.05351845850886158 (2147 errors out of 40117)

error rate by sentence: 0.6470588235294118 (1100 errors out of 1700)

It is slightly better than the Perl version.



The screenshot displays an IDE with a project named 'Homework 2 Final'. The file explorer on the left shows various files, including 'japanese_bigram.hmm', 'japanese_bigram.out', 'japanese_trigram.out', 'model_performance_analysis.py', 'my.hmm', 'my.out', 'predictions_ptb22.out', 'ptb.23.out', 'python.out', 'README', 'Sentence Error Rate.png', 'tag_acc.py', 'test.py', 'train_hmm.py', 'tri_viterbi.py', 'trigram.hmm', 'trigram.out', 'trigram_hmm.py', and 'trigram_test.py'. The main editor window shows the 'viterbi.py' file with the following code:

```
97 print(' '.join(reversed(ans_list)))
98 else:
99 print(' ')
100
101
102 if __name__ == "__main__":
103     HMM_FILE = sys.argv[1]
104     TOKEN_FILE = sys.argv[2]
105     emissions, transitions, all_states, vocabulary = preprocess(HMM_FILE)
106     viterbi_algorithm(TOKEN_FILE, emissions, transitions, all_states, vocabulary)
107
```

The terminal at the bottom shows the execution of the program:

```
(base) sankalpapharande@Sankalps-MBP Homework 2 Final % clear
(base) sankalpapharande@Sankalps-MBP Homework 2 Final % python viterbi.py my.hmm data/ptb.22.txt > python.out
(base) sankalpapharande@Sankalps-MBP Homework 2 Final % python tag_acc.py data/ptb.22.tgs python.out
error rate by word:      0.05351845850886158 (2147 errors out of 40117)
error rate by sentence:  0.6470588235294118 (1100 errors out of 1700)
(base) sankalpapharande@Sankalps-MBP Homework 2 Final %
```

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Part 2:

trigram HMM and Trigram Viterbi

Trigram_hmm.py contains training for generating trigram HMM and the corresponding Viterbi algorithm which uses Trigram HMM.

I have used a simple backoff model. It is giving better performance than naive trigram

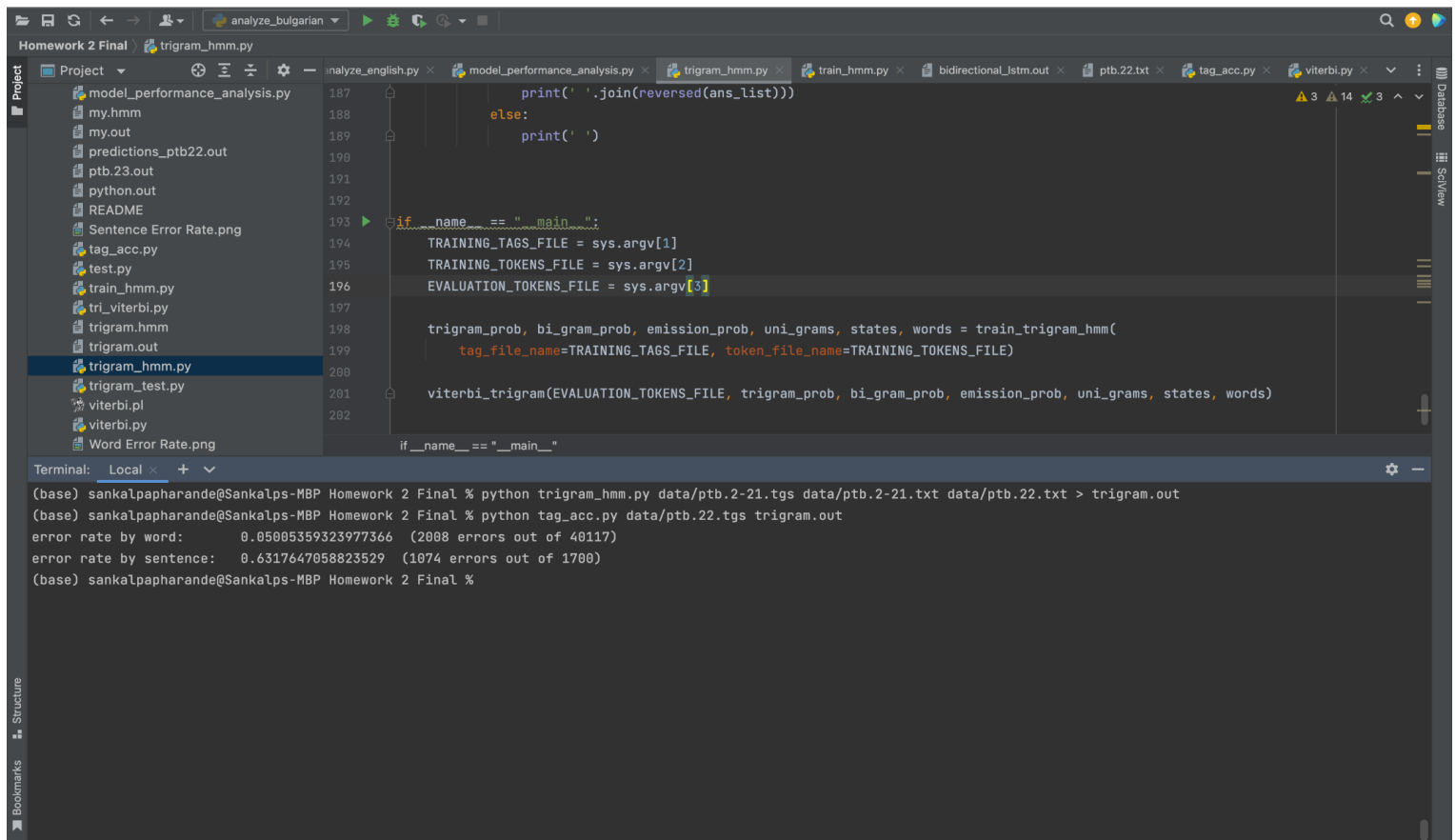
To generate tags for ptb.23.txt; Run:

```
python trigram_hmm.py data/ptb.2-21.tgs data/ptb.2-21.txt data/ptb.23.txt > ptb.23.out
```

Results: model's performance on the development data (ptb.22.txt)

error rate by word: 0.05005359323977366 (2008 errors out of 40117)

error rate by sentence: 0.6317647058823529 (1074 errors out of 1700)



The screenshot shows a code editor with the file `trigram_hmm.py` open. The code includes a `__main__` block that takes command-line arguments for training and evaluation files. The terminal output at the bottom shows the execution of the script, resulting in the same error rates as mentioned in the text.

```
187 print(' '.join(reversed(ans_list)))
188 else:
189     print(' ')
190
191
192
193 if __name__ == "__main__":
194     TRAINING_TAGS_FILE = sys.argv[1]
195     TRAINING_TOKENS_FILE = sys.argv[2]
196     EVALUATION_TOKENS_FILE = sys.argv[3]
197
198     trigram_prob, bi_gram_prob, emission_prob, uni_grams, states, words = train_trigram_hmm(
199         tag_file_name=TRAINING_TAGS_FILE, token_file_name=TRAINING_TOKENS_FILE)
200
201     viterbi_trigram(EVALUATION_TOKENS_FILE, trigram_prob, bi_gram_prob, emission_prob, uni_grams, states, words)
202
203 if __name__ == "__main__":
```

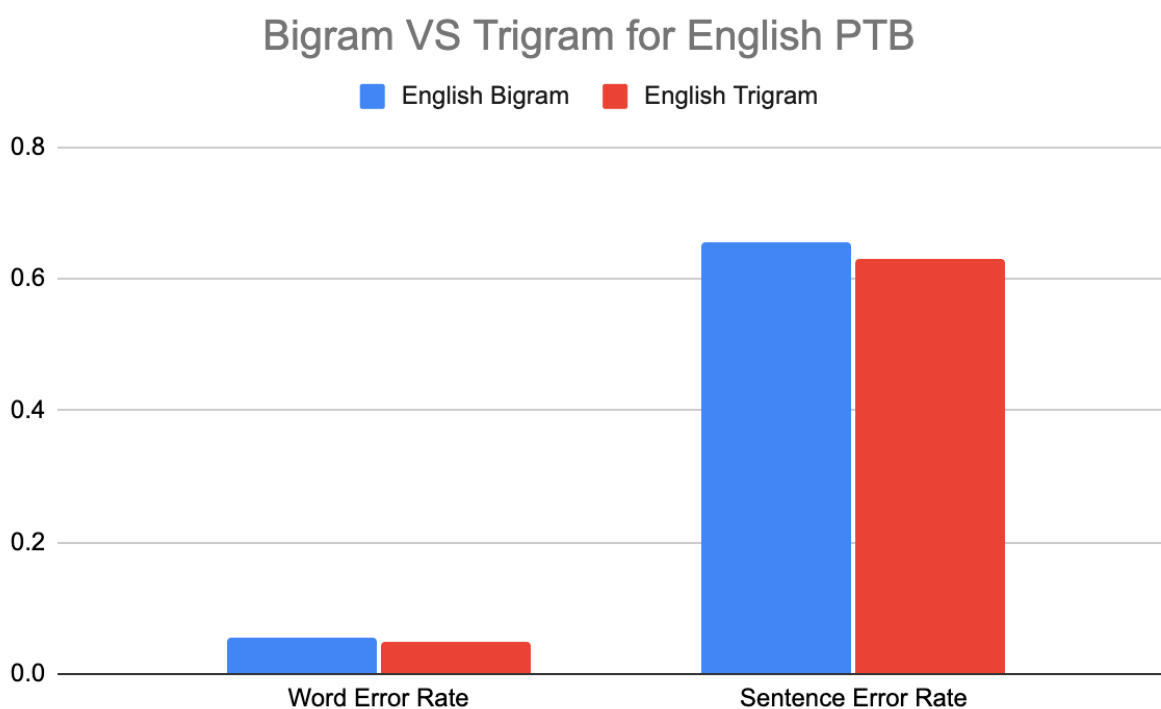
```
(base) sankalpapharande@Sankalps-MBP Homework 2 Final % python trigram_hmm.py data/ptb.2-21.tgs data/ptb.2-21.txt data/ptb.23.txt > trigram.out
(base) sankalpapharande@Sankalps-MBP Homework 2 Final % python tag_acc.py data/ptb.22.tgs trigram.out
error rate by word: 0.05005359323977366 (2008 errors out of 40117)
error rate by sentence: 0.6317647058823529 (1074 errors out of 1700)
(base) sankalpapharande@Sankalps-MBP Homework 2 Final %
```

POS Tagging: Viterbi Algorithm and Deep Learning Comparision

Bigram vs Trigram comparision for ENG Penn Tree Bank dataset:

Trigram is better than Bigram:

	English Bigram	English Trigram
Word Error Rate	0.05409178154	0.05005359324
Sentence Error Rate	0.6558823529	0.6317647059



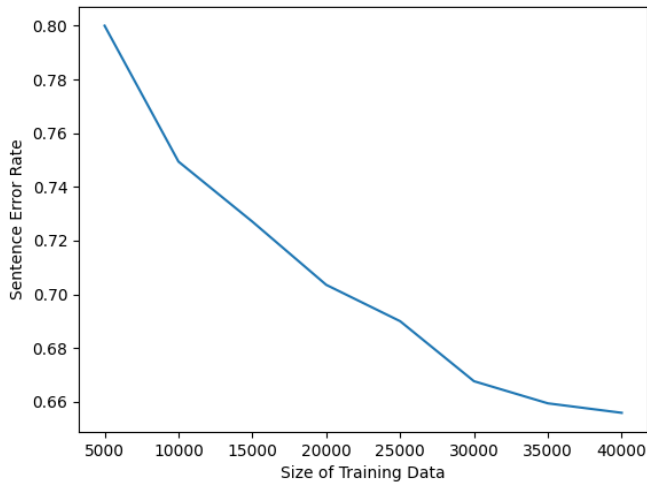
POS Tagging: Viterbi Algorithm and Deep Learning Comparison

Task 2

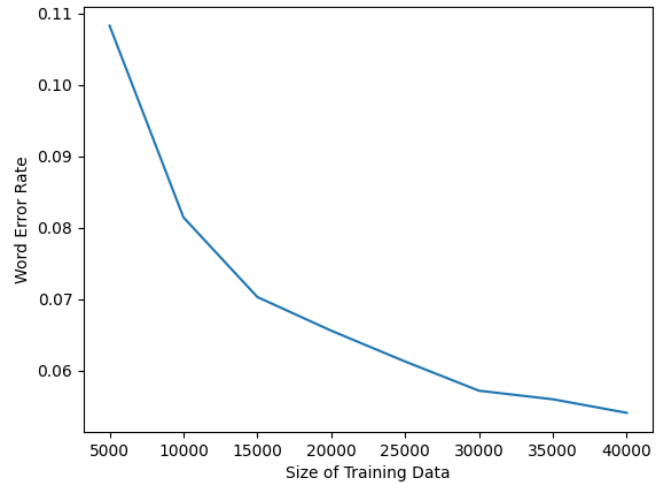
Generating learning curve for bigram HMM evaluation

In the code, to generate curves, run

python model_performance_analysis.py



Sentence Error Rate vs Size of Training Data



Word Error Rate VS Size of Training Data

Observation:

1. Both sentence error rate and Word error rate decreases as the size of training data increases.
2. As expected, getting more training data is always helpful.
3. Getting more POS-tagged data would help decrease error rates
4. But improvement in the model gradually decreases as the training data size increases, i.e decrease in error rate is not as fast as it is initially.

POS Tagging: Viterbi Algorithm and Deep Learning Comparison

Task 3

Part 1:

Q. Train the bigram model and your trigram model on the Japanese (jv.*) and Bulgarian (btb.*) training datasets, and compare them on the test sets. Report the performance and compare the performance differences between English, Japanese, and Bulgarian.

I have created separate python scripts to analyze the performance of these 3 languages.

1. English: To generate bigram and Trigram output for English

Run:

python analyze_english.py

2. Japanese: To generate bigram and Trigram output for Japanese

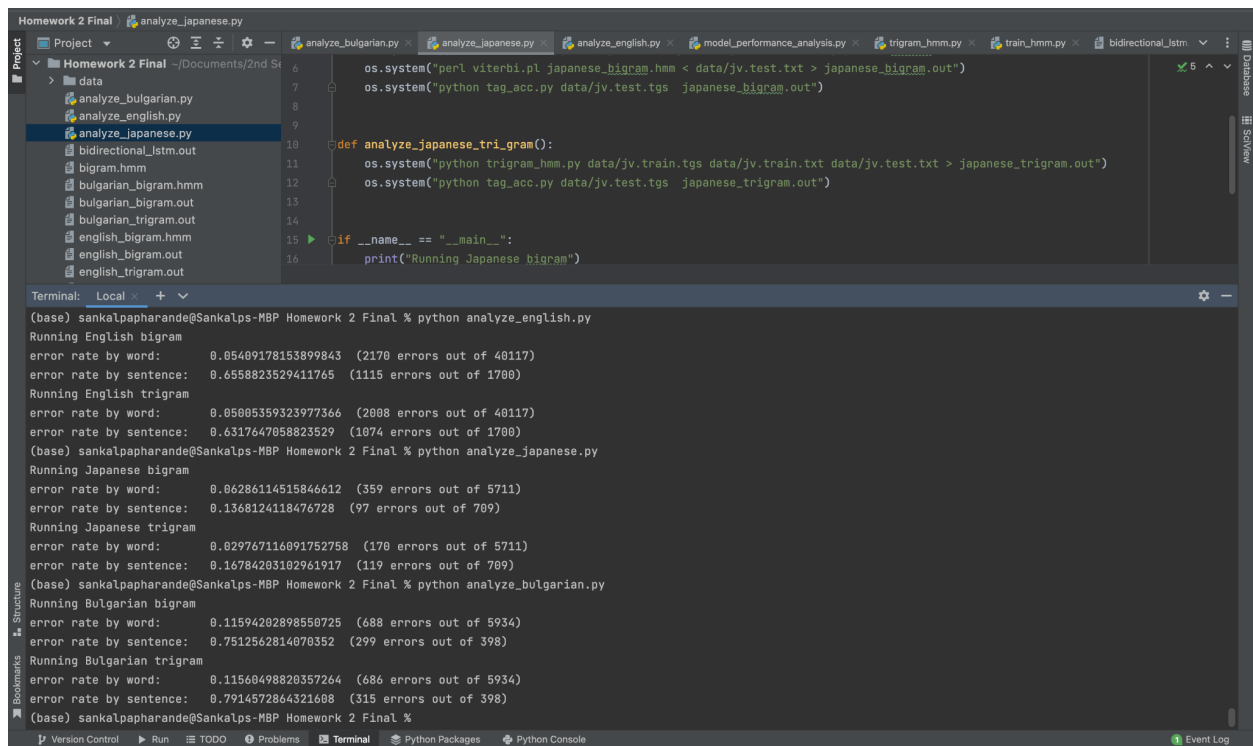
Run:

Python analyze_japanese.py

3. Bulgarian: To generate bigram and trigram output for Bulgarian.

Run:

Python analyze_bulgarian.py



```
Homework 2 Final - analyze_japanese.py
Project
  Homework 2 Final - /Documents/2nd S...
    data
      analyze_bulgarian.py
      analyze_english.py
      analyze_japanese.py
      bidirectional_lstm.out
      bigram.hmm
      bulgarian_bigram.hmm
      bulgarian_bigram.out
      bulgarian_trigram.out
      english_bigram.hmm
      english_bigram.out
      english_trigram.out
    analyze_bulgarian.py
    analyze_japanese.py
    analyze_english.py
    model_performance_analysis.py
    trigram_hmm.py
    train_hmm.py
    bidirectional_lstm.py
  6 os.system("perl viterbi.pl japanese_bigram.hmm < data/jv.test.txt > japanese_bigram.out")
  7 os.system("python tag_acc.py data/jv.test.tgs japanese_bigram.out")
  8
  9
 10
 11 def analyze_japanese_tri_gram():
 12     os.system("python trigram_hmm.py data/jv.train.tgs data/jv.train.txt data/jv.test.txt > japanese_trigram.out")
 13     os.system("python tag_acc.py data/jv.test.tgs japanese_trigram.out")
 14
 15
 16 if __name__ == "__main__":
 17     print("Running Japanese bigram")

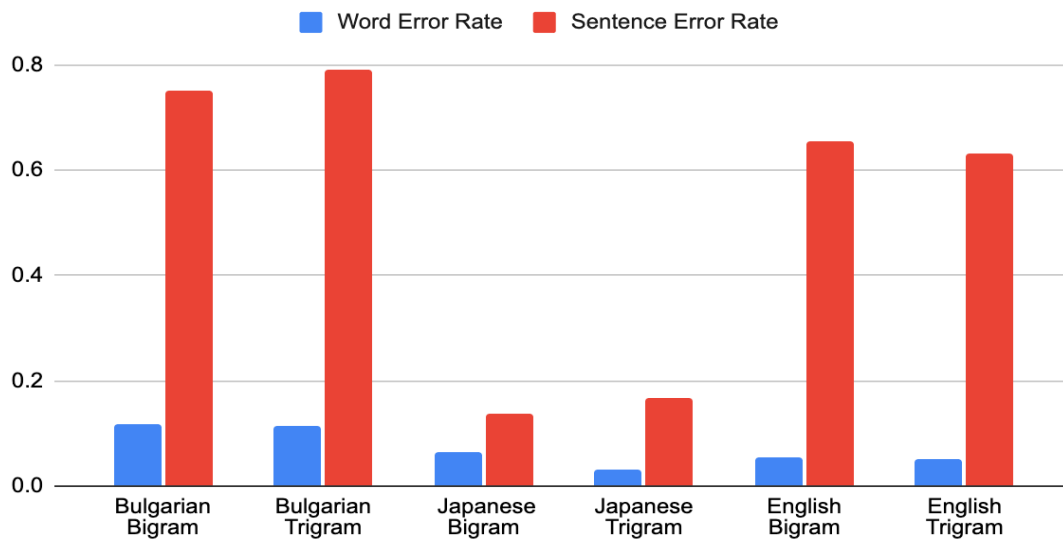
Terminal: Local
(base) sankalpapharande@Sankalps-MBP Homework 2 Final % python analyze_english.py
Running English bigram
error rate by word: 0.05409178153899843 (2178 errors out of 40117)
error rate by sentence: 0.6588823529411765 (1115 errors out of 1700)
Running English trigram
error rate by word: 0.05005359323977366 (2008 errors out of 40117)
error rate by sentence: 0.6317647058823529 (1074 errors out of 1700)
(base) sankalpapharande@Sankalps-MBP Homework 2 Final % python analyze_japanese.py
Running Japanese bigram
error rate by word: 0.06286114515846612 (359 errors out of 5711)
error rate by sentence: 0.1368124118476728 (97 errors out of 709)
Running Japanese trigram
error rate by word: 0.029767116091752758 (170 errors out of 5711)
error rate by sentence: 0.16784203102961917 (119 errors out of 709)
(base) sankalpapharande@Sankalps-MBP Homework 2 Final % python analyze_bulgarian.py
Running Bulgarian bigram
error rate by word: 0.11594202898550725 (688 errors out of 5934)
error rate by sentence: 0.7512562814070352 (299 errors out of 398)
Running Bulgarian trigram
error rate by word: 0.11560498820357264 (686 errors out of 5934)
error rate by sentence: 0.7914572864321608 (315 errors out of 398)
(base) sankalpapharande@Sankalps-MBP Homework 2 Final %
```

POS Tagging: Viterbi Algorithm and Deep Learning Comparision

Performance differences between these languages:

	Bulgarian Bigram	Bulgarian Trigram	Japanese Bigram	Japanese Trigram	English Bigram	English Trigram
Word Error Rate	0.115942029	0.1156049882	0.06286114516	0.02976711609	0.05409178154	0.05005359324
Sentence Error Rate	0.7512562814	0.7914572864	0.1368124118	0.167842031	0.6558823529	0.6317647059

Word Error Rate and Sentence Error Rate



Observations:

1. Both Bigram and Trigram perform best on Japanese Data
2. Performace is worst for Bulgarian Language
3. Trigram performs better for English than corresponding Bigram
4. For Bulgarian, Trigram performs worse than bigram

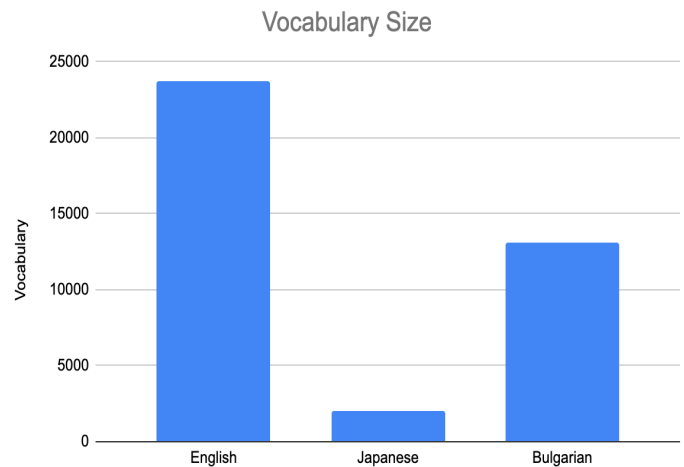
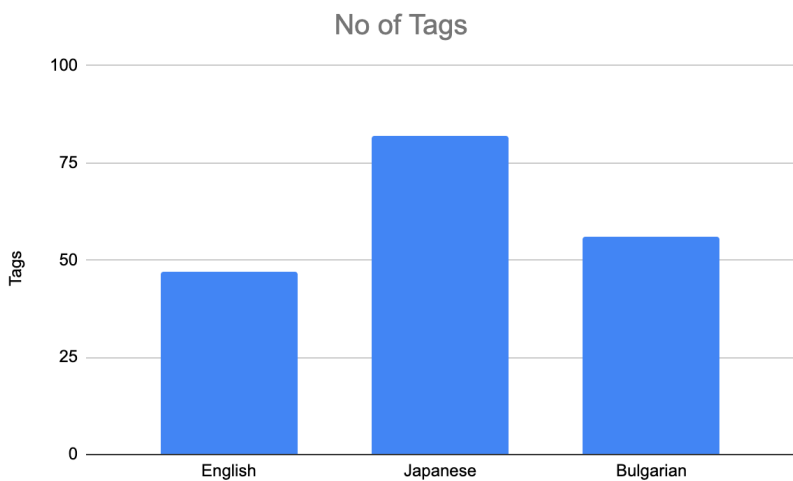
POS Tagging: Viterbi Algorithm and Deep Learning Comparision

Part 2

You could look at the data and give some analysis – what factors lead to the differences among performance on English, Japanese, and Bulgarian? (

Data Analysis:

	English	Japanese	Bulgarian
Tags	47	82	56
Vocabulary	23768	2030	13122



Observations:

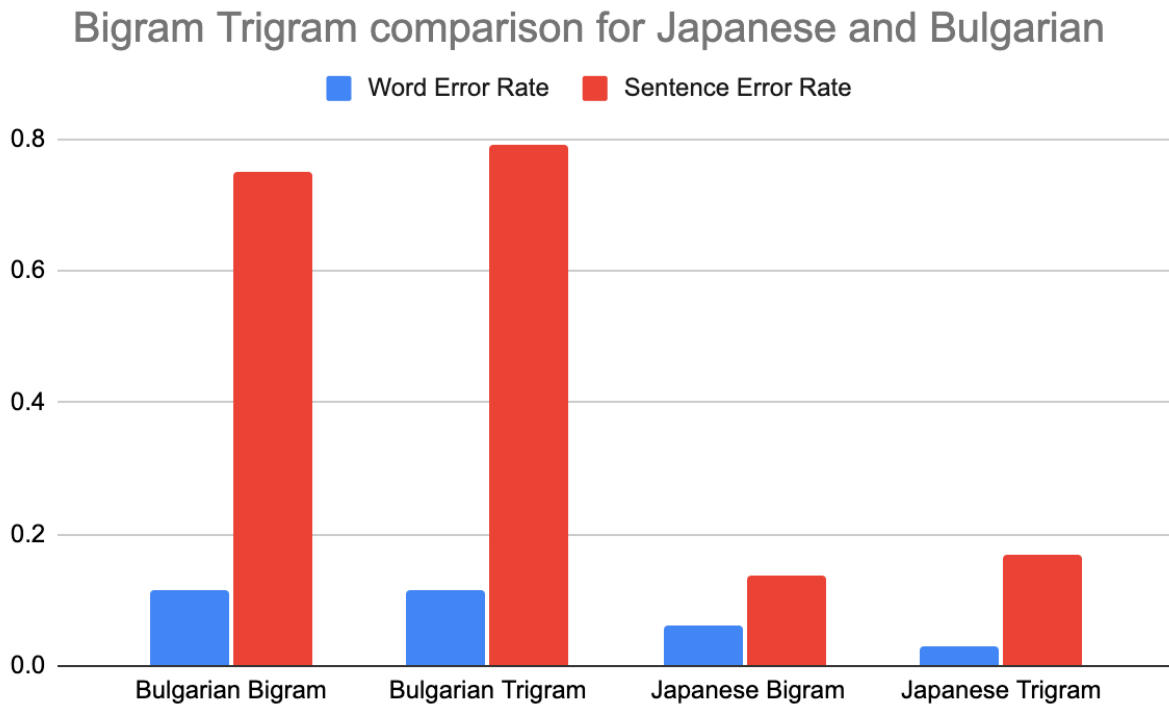
1. Japanese has the highest number of tags 76 and smallest vocabulary size among given three languages.
2. Markov assumption is holding much better for Japanese, possibly because In English, a sentence is written word-by-word. On the other hand. A sentence in Japanese has no word boundary character. ([Source](#))
3. In Bulgarian Language, the Markov assuption is not that strong.
4. English is relatively better because enough words in English sentence depends on previous word. Even better when we use trigram
5. Hence HMM Bigram has best performance for Japanese, then English and worst for Bulgarian

POS Tagging: Viterbi Algorithm and Deep Learning Comparison

Part 3

what about the trigram HMM makes them relatively better or worse on the data in these two languages? Explain your result.

Trigram comparison for Japanese and Bulgarian:



Observation:

1. Bigram performs better for Japanese and Bulgarian

Reason:

- a. Markov assumption is holding much better for Japanese. A sentence in Japanese has no word boundary character. ([Source](#))
- b. In Bulgarian Language, the Markov assumption is not that strong.

2. Both Bigram and Trigram perform better for Japanese than Bulgarian

Reason:

- a. Both in Japanese and Bulgarian, long dependencies are not helpful. It could be because there are no word boundaries in Japanese and Bulgarian like English

3. Word Error is smaller in trigram than Bigram for Japanese

Reason:

- a. Trigram is helpful to identify the tags but not good to identify the sequence of tags

4. Sentence Error rate are higher in Trigram for both Japanese and Bulgarian

Reason

- a. Markov assumption is not that strong in these Bulgarian and long dependencies are not helpful in identifying sequence

POS Tagging: Viterbi Algorithm and Deep Learning Comparision

Bonus Task:

1. Implemented Bidirectional LSTM with Word Embeddings are initial weights for English
2. Implemented Bidirectional LSTM without word Embeddings for Japanese and Bulgarian because I could not find word embeddings in these languages

Resons for LSTM:

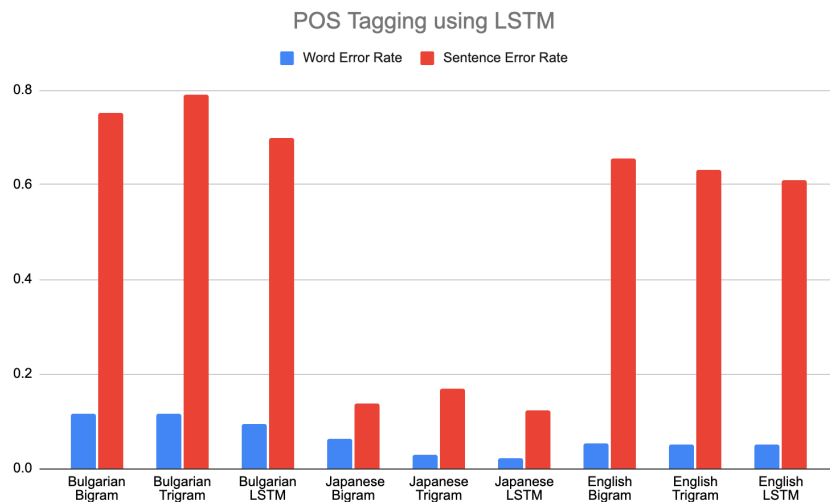
1. LSTM are a form of Recurrent Neural Network which is helpful in learning many to many sequence learning
2. LSTM handles Vanishing and Exploding gradient problem by implementing forget gate and Add Gate
3. Birdirectional learns from both the ends hence good for POS Tagging

Colab Notebooks can be found [here](#):

Reference: <https://nlpforhackers.io/lstm-pos-tagger-keras/>

Methodology:

1. English:
 - a. Trained and Validated using data/ptb.2-21.tgs data/ptb.2-21.txt/ and
 - b. Evaluated on data/ptb.22.txt and data/ptb.22.tgs
2. Japanese:
 - a. Trained and Validated using data/jv.train.tgs data/jv.train.txt
 - b. Evaluated on data/jv.test.txt and data/jv.test.tgs
3. Bulgarian:
 - a. Trained and Validated using data/btb.train.tgs data/btb.train.txt
 - b. Evaluated on data/btb.test.txt and data/btb.test.tgs



Observations:

1. Bidirectional LSTM Performs better than both bigram and trigram for all three languages
2. Both Sentence Error Rate and Word Error Rate is lowest using LSTM for all three languages.

POS Tagging: Viterbi Algorithm and Deep Learning Comparision

	Bulgarian Bigram	Bulgarian Trigram	Bulgarian LSTM	Japanese Bigram	Japanese Trigram	Japanese LSTM	English Bigram	English Trigram	English LSTM
Word Error Rate	0.115942029	0.115604988	0.094202	0.062861	0.029767	0.0211871	0.0540917	0.0500535	0.04997353687
Sentence Error Rate	0.7512562814	0.79145728	0.698492	0.136812	0.167842	0.122708	0.6558823	0.6317647	0.6088390501

Acknowledgement and References:

1. <https://github.com/KangboLu/Natural-Language-Processing>
2. <https://github.com/nadiahyder/POS-Tagger>
3. <https://www.kaggle.com/code/tanyadayanand/pos-tagging-using-rnn/notebook>
4. <https://www.pythonpool.com/viterbi-algorithm-python/>