

Github Repo :

https://github.com/raghavchugh21/NLP_Coursework/blob/main/NLP_Project_1.ipynb

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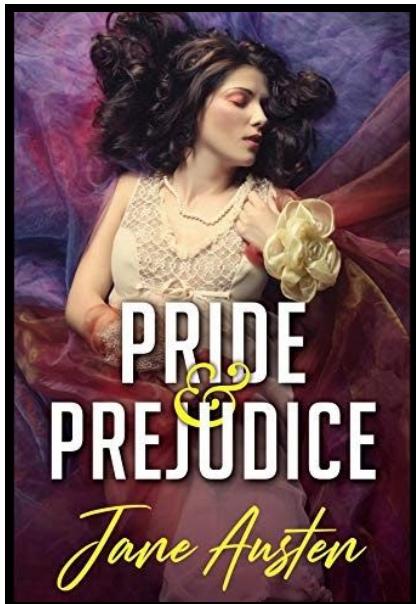
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NLP PROJECT ROUND 1

OVERVIEW

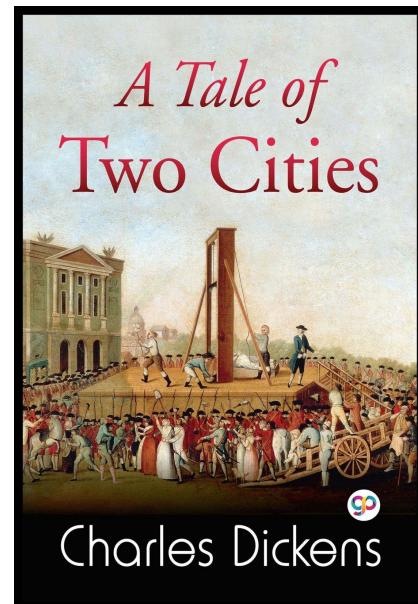
In this project, we perform text analysis on two of our chosen books from Gutenberg. “Pride and Prejudice” and “A Tale of Two Cities”. After that we will go forward and apply POS Tagging on both the books. We will do all this using NLP techniques, with the help of python libraries.

BOOKS USED



Pride and Prejudice

By Jane Austen



A Tale of Two Cities

By Charles Dickens

GOALS

1. Import the text from two books, let's call it as T1 and T2.
2. Perform simple text pre-processing steps and tokenize the text T1 and T2.
3. Analyze the frequency distribution of tokens in T1 and T2 separately.
4. Create a Word Cloud of T1 and T2 using the token that you have got.
5. Remove the stopwords from T1 and T2 and then again create a word cloud.
6. Compare with word clouds before the removal of stopwords.
7. Evaluate the relationship between the word length and frequency for both T1 and T2.
8. Do PoS Tagging for both T1 and T2 using anyone of the four tagset studied in the class and Get the distribution of various tags

SPECIFICATIONS

Python Libraries used in this project

Urllib - Used to fetch text data from Gutenberg URLs

NLTK - Used for Tokenizing, Lemmatization and Removing Stopwords

Re - Used to remove URLs and Decontract Contractions in English Language

Wordcloud - Used to create WordClouds from Tokenized Data

Inflect - Used to replace numbers with words

Mapplotlib - Used to Visualize our text data

MILESTONES

Data Description

After Importing from URL, sample book data would look like :

b'\x0f\xbb\xbf\r\nThe Project Gutenberg EBook of Pride and Prejudice, by Jane Austen\r\n\r\nThis eBook is for the use of anyone anywhere at no cost and with\r\nalmost no restrictions whatsoever. You may copy it, give it away or\r\nre-use it under the terms of the Project Gutenberg License included\r\nwith this eBook or online at

We infer that :

- The book contains legal documentation which is of no use to us (Before “START OF THIS PROJECT” and after “END OF THIS PROJECT”)
 - There are numbers that are not meaningful to us directly, so we need to convert them to words
 - There are a lot of contractions and punctuations in english and we need to convert them to meaningful data
 - There are a lot of special characters, URLs
 - There are no emojis, emoticons, or chat words

Data Preprocessing Steps

1. Discard Useless Portion of Book

We will discard the documentation part of the book that is of no use to us.

```
def discard_useless_part (text):
    sidx = text.find('*** START OF THIS PROJECT ')
    eidx = text.find('*** END OF THIS PROJECT ')
    print("Discarding Before - ", sidx)
    print("Discarding After - ", eidx)
    text = text[sidx:eidx]
    return text
```

2. Convert all data to lowercase

We will convert all text data to lowercase, as the case does not contribute much to the meaning of data.

```
def to_lower(text):
    return text.lower()
```

3. Converting Number to Words

For this, we use inflect Python Library which has a function p.number_to_words that will give us the english equivalent of a number using basic mapping techniques.

```
def num2word(text):
    list_of_words = text.split()
    modified_text = []

    for word in list_of_words:
        if word.isdigit():
            number_in_word = p.number_to_words(word)
            modified_text.append(number_in_word)
        else:
            modified_text.append(word)

    return ' '.join(modified_text)
```

4. Removing Contractions and Punctuations

We will do this using a Python Library `re` that will help us apply regular expressions on our data as desired.

```
def decontracted(text)
    # specific
    text = re.sub(r"won't", "will not", text)
    text = re.sub(r"can't", "can not", text)

    # general
    text = re.sub(r"\n\t", " not", text)
    text = re.sub(r"\'re", " are", text)
    text = re.sub(r"\'s", " is", text)
    text = re.sub(r"\d", " would", text)
    text = re.sub(r"\ll", " will", text)
    text = re.sub(r"\t", " not", text)
    text = re.sub(r"\'ve", " have", text)
    text = re.sub(r"\'m", " am", text)
    return text

def remove_punctuation(text):
    tokens = word_tokenize(text)
    words = [word for word in tokens if word.isalpha()]
    return ' '.join(words)
```

5. Removing URLs

Again, we would do this using `re`

```
def remove_URL(text):
    return re.sub(r"http\S+", "", text)
```

6. Lemmatization

We do Lemmatization with the help of `WordNetLemmatizer()` function from `nltk.stem` which gives the lemmatized form of all verbs

```
def lemmatize_word(text):
    word_tokens = word_tokenize(text)
    lemmas = [lemmatizer.lemmatize(word, pos ='v') for word in word_tokens]
    return ' '.join(lemmas)
```

Data Preparation

We apply all the functionalities we added above and Prepare our data for analysis.

```
def PreProcessedBook(url):
    book = read_book(url)
    print_book_title_and_length(book)
    text = decode_book(book)
    text = discard_useless_part(text)
    text = to_lower(text)
    text = remove_URL(text)
    text = decontracted(text)
    text = num2word(text)
    text = remove_punctuation(text)
    text = lemmatize_word(text)
    return (text)
```

```
book1_text = PreProcessedBook(url1)
book2_text = PreProcessedBook(url2)
```

Problem Statements and Inferences

- Analyze the frequency distribution of tokens in T1 and T2 separately

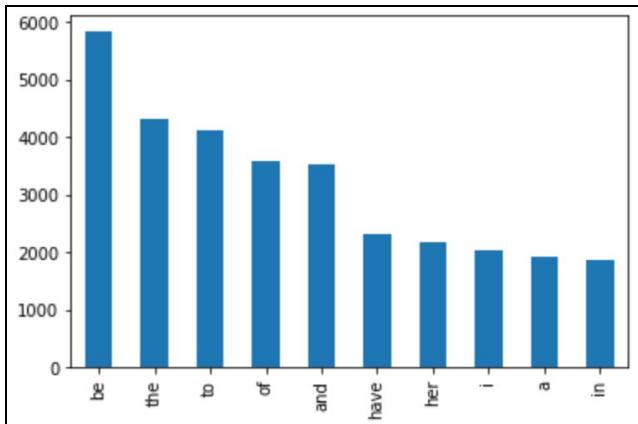
For this step, we take help of python library **pandas**

First we tokenize the given data, and then we plot a histogram of top 10 most frequent words.

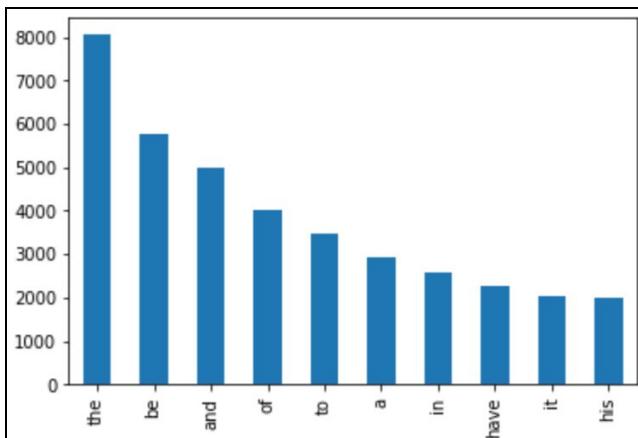
```
T1 = word_tokenize(book1_text)
pd.Series(T1).value_counts()[:10].plot(kind='bar')
```

```
T2 = word_tokenize(book2_text)
pd.Series(T2).value_counts()[:10].plot(kind='bar')
```

Frequency Distribution of T1



Frequency Distribution of T2

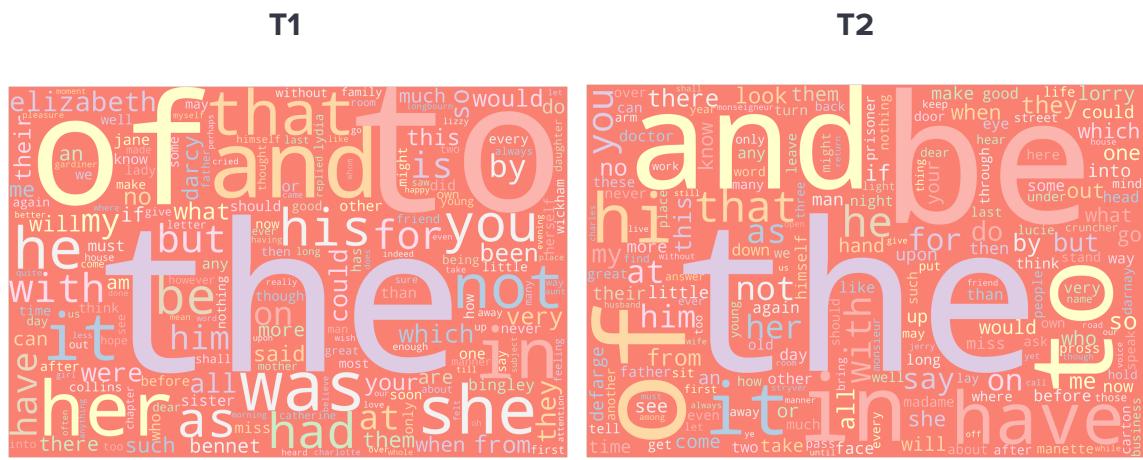


- Generating a word cloud from T1 and T2

For this we take the help of a python library `wordcloud` and its function `WordCloud`.

It helps in generating wordclouds from a list of Tags from Text data

```
# Generate word cloud
wordcloud = WordCloud(width = 3000, height = 2000, random_state=1,
                      background_color='salmon', colormap='Pastel1',stopwords= [],
                      collocations=False).generate(' '.join(T1))
# Plot
plot_cloud(wordcloud)
```



Inferences

We infer from the above visualizations that

- Words like ‘of’, ‘to’ and ‘the’ are the most frequently used words in T1
 - Words like ‘of’, ‘and’, ‘be’ and ‘the’ are frequently used words in T2
 - These words do not contribute to the meaning of the sentence and are mostly useless for us
 - These words are known as ‘stopwords’ and we need to get rid of them

- Generating new word clouds after removing stopwords

To remove stopwords, we use an inbuilt function in `nltk` called `STOPWORDS`

```
def remove_stopwords(tokens):
    return [word for word in tokens if word not in STOPWORDS]
```

```
T1 = remove_stopwords(T1)  
T2 = remove_stopwords(T2)
```



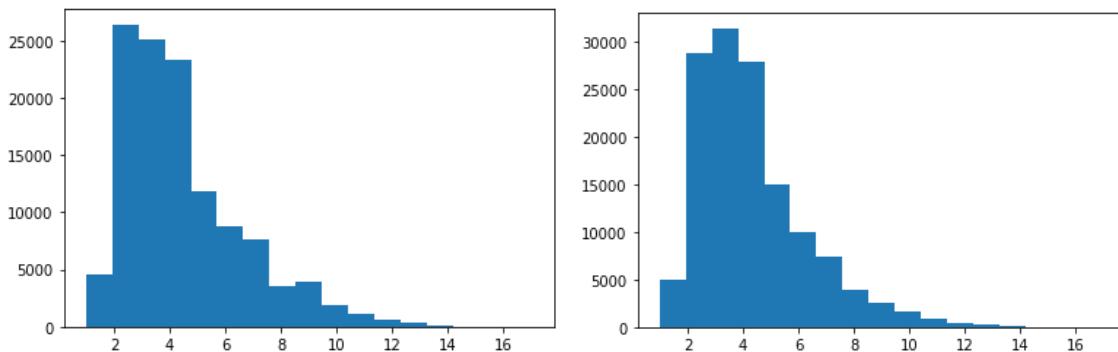
Inferences

We infer from the above visualizations that

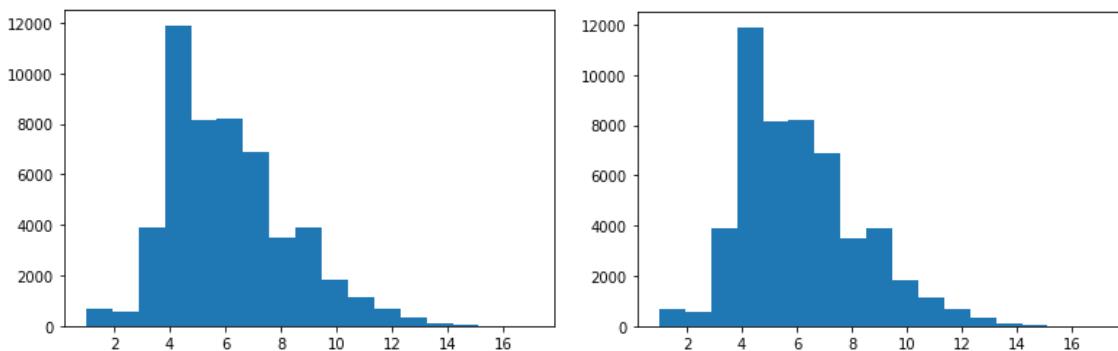
- Now most of the words that were of no meaning to us have been removed.
 - New words like ‘elizabeth’, ‘darcy’ and ‘bennet’ now dominate in frequency in T1 which sort of reveals the name of characters of the book around whom the story will revolve.
 - Words like ‘say’, ‘look’, ‘one’ and ‘go’ are the new frequently used words in T2, though it is tough to make inferences based on this information but we are able to roughly guess that there is some ‘doctor’ and ‘Lorry’ in the story.
 - We have gotten rid of ‘stopwords’ and are now able to draw meaningful conclusions from the data.

- As a part of the project, we would also like to evaluate the relationship between the word length and frequency for both T1 and T2 both before and after the removal of stopwords

Before



After



Inferences

We infer from the above visualizations that

- The number of words of length 2 and 3 have significantly decreased after the removal of stopwords.
- We can clearly infer that this is due to the removal of stopwords like 'be', 'the', 'of' and 'and' which were the highest occurring words before removal.
- Apart from that there is a general trend that the highest number of words lie in length range 3-6, and there is a significant decrease in frequency of words with either a length lesser than this or more than this.

- **Performing POS Tagging**

We will now perform the POS Tagging on T1 and T2 using inbuilt functions of **nltk** namely **post_tag()** which uses Penn Treebank tag set to perform POS tagging.

```
def tag_treebank(tokens):
    tagged=nltk.pos_tag(tokens)
    return tagged
```

```
book1_tags=tag_treebank(T1)
book2_tags=tag_treebank(T2)
print(book1_tags)
```

```
('start', 'NN')
('project', 'NN')
('gutenberg', 'NN')
('ebook', 'NN')
('pride', 'NN')
('prejudice', 'NN')
('produce', 'VBP')
('anonymous', 'JJ')
('volunteer', 'NN')
('david', 'NN')
('widger', 'NN')
('illustrate', 'VBP')
('edition', 'NN')
('title', 'NN')
('may', 'MD')
('view', 'VB')
('ebook', 'NN')
('thousand', 'CD')
('six', 'CD')
('hundred', 'VBD')
```

- **Frequency Distribution of Tags**

Now, we plot the frequency distribution of tags after POS tagging on T1 and T2. For this we take the help of **Counter()** function from **collections** python library and **FreqDist()** function from nltk python library.

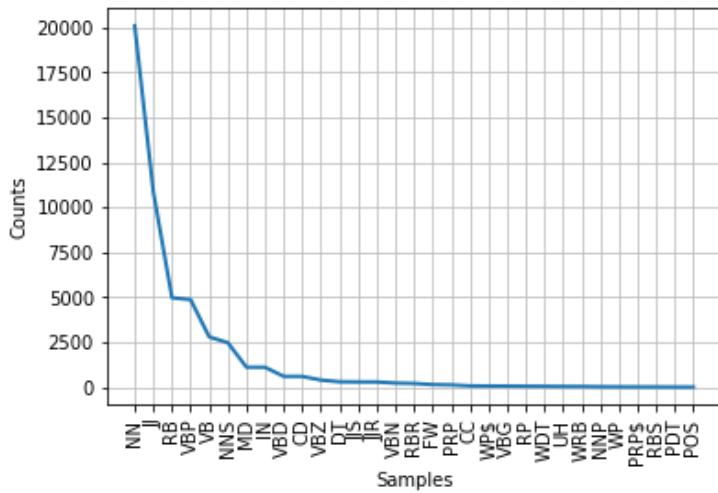
```
def get_counts(tags):
    counts = Counter( tag for word, tag in tags)
    return counts
```

```
def FrequencyDist(tags):
    wfd=FreqDist(t for (w,t) in tags)
    wfd.plot(50)
```

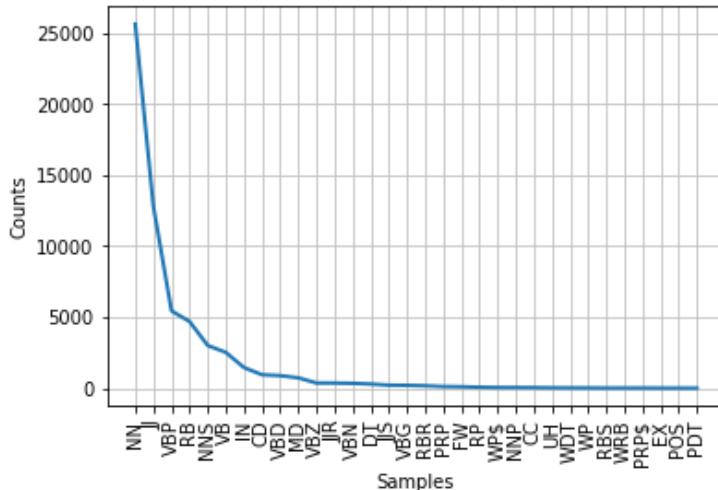
```
book1_pos_count=get_counts(book1_tags)
book2_pos_count=get_counts(book2_tags)
```

```
FrequencyDist(book1_tags)
FrequencyDist(book2_tags)
```

Frequency Distribution of Tags in T1



Frequency Distribution of Tags in T2



Inferences

From the above results we infer that the highest occurring tag is ‘NN’, and ‘Determinant’ Tags are on the lower frequency side. This is largely due to the removal of stopwords before POS Tagging.

Conclusion

We have learnt how to perform Text Preprocessing, Tokenization on Text Data and then answer all the Problems given to us in NLP Project Round 1 with the use of Plots and Visualisations and learnt to draw meaningful inferences from it.

PROJECT ROUND 2

GOALS

1. Import the text from two books, let's call it as T1 and T2.
2. Perform simple text pre-processing steps and tokenize the text T1 and T2.
- 3 .Find the nouns and verbs in both the novels. Get the categories that these words fall under in the WordNet. Note that there are 25 categories and 16 categories for Nouns and Verbs respectively.
4. Get the frequency of each category for each noun and verb in their corresponding hierarchies and plot histogram/bar plots for each corresponding categories
5. Recognise all Persons, Location, Organisation (Types given in Fig 22.1) in book. For this you have to do two steps: (1) First recognise all the entity and then (2) recognise all entity types. Use performance measures to measure the performance of the method used, use random samples to measure the performance.
- 6.Extract the relationship between the entities (mainly the characters involved in the novel)

SPECIFICATIONS

Python Libraries used in this project :

Urllib - Used to fetch text data from Gutenberg URLs

NLTK - Used for Tokenizing, implementing wordnet, POS tagging etc.

Re - Used to remove URLs and Decontract Contractions in English Language

Matplotlib - Used to Visualize our text data

Spacy- To perform Entity recognition in text

Numpy- To get frequency distributions of nouns and verbs

Typing-To perform evaluation of the Algorithm in Entity Recognition.

Problem Statement And Inferences:

NOUNS and VERBS Detection

• Performing POS Tagging

We will now perform the POS Tagging on T1 and T2 using inbuilt functions of nltk namely pos_tag() which uses Penn Treebank tag set to perform POS tagging.

We will extract the words which are tagged explicitly as nouns and verbs separately from both the novels using the following functions.

```
def noun(text):
    is_noun = lambda pos: pos[:1] == 'N'
    tokenized = nltk.word_tokenize(text)
    nouns = [word for (word, pos) in nltk.pos_tag(tokenized) if is_noun(pos)]
    return nouns
```

```
noun1=noun(book1_text)
noun2=noun(book2_text)
```

```
def verb(text):
    is_verb = lambda pos: pos[:1] == 'V'
    tokenized = nltk.word_tokenize(text)
    verbs = [word for (word, pos) in nltk.pos_tag(tokenized) if is_verb(pos)]
    return verbs
```

```
verb1=verb(book1_text)
verb2=verb(book2_text)
```

We will apply the above functions to both book1 and book2 respectively and print the total nouns and verbs in both of them.

```
print("Number of nouns in book 1 and book 2 respectively are "+ str(len(noun1))+" and "+ str(len(noun2)))
Number of nouns in book 1 and book 2 respectively are 23981 and 31305
```

```
print("Number of verbs in book 1 and book 2 respectively are "+ str(len(verb1))+" and "+ str(len(verb2)))
Number of verbs in book 1 and book 2 respectively are 21811 and 22054
```

1. Get the categories that these words fall under in the WordNet.

To retrieve the categories that each noun and verb belong to, in the wordnet synsets, we have used nltk.corpus.wordnet as it has all the tools required for this task. We have used the following function to extract categories each noun and verb belongs to. Since a noun also has synsets interpretations as verbs and vice versa hence we have included them as lists corresponding to its index in the noun and verb lists respectively.

```
#gives the categories of nouns or verb that the word belongs to
from nltk.corpus import wordnet as wn
def synset(words):
    categories=[]
    for word in words:
        cat=[]
        for synset in wn.synsets(word):
            if('noun' in synset.lexname() & ('Tops' not in synset.lexname())):
                cat.append(synset.lexname())
            if('verb' in synset.lexname()):
                cat.append(synset.lexname())
        categories.append(cat)
    return categories
```

We will apply the above function to get 2-D lists which contains the categories that each noun and verb have been defined in the wordnet database.

```
noun_syn1=synset(noun1)
noun_syn2=synset(noun2)
verb_syn1=synset(verb1)
verb_syn2=synset(verb2)
```

Hence noun_syn1, noun_syn2, verbsyn_1,verb_syn2 are 2 dimensional lists which contain the categories that noun1,noun2,verb1,verb2 belong to in the wordnet synsets of nouns and verbs.

The 2d lists are indexed as noun_syn1[x][y] where x is the index of corresponding noun in noun1 and y is the index containing the categories it belongs to.

Eg.

```
print(noun1[88])
neighbourhood

print(noun_syn1[88][:])
['noun.location', 'noun.group']
```

Hence a ‘neighbourhood’ is both a place and a group of people.

- Get the frequency of each category for each noun and verb in their corresponding and plot histogram/bar plots for each corresponding categories.

To get the frequency of all the categories of nouns and verbs in the novels, we have created a set for each novel which contains all the types of nouns and verbs occurring and then plotting the frequency distribution for the data.

```
#GIVES TOTAL NOUN LEXNAMES AND TOTAL VERB LEXNAMES FOR FREQUENCY DISTRIBUTIONS
def all_synsets(no,ve):
    nouns=[]
    verbs=[]
    for word in no:
        for synset in wn.synsets(word):
            if('noun' in synset.lexname() & ('Tops' not in synset.lexname())):
                nouns.append(synset.lexname())
            if('verb' in synset.lexname()):
                verbs.append(synset.lexname())
    for word in ve:
        for synset in wn.synsets(word):
            if(('noun' in synset.lexname() & ('Tops' not in synset.lexname())):
                nouns.append(synset.lexname())
            if('verb' in synset.lexname()):
                verbs.append(synset.lexname())

    return nouns,verbs
```

```
noun_superset1,verb_superset1=all_synsets(noun1,verb1)
noun_superset2,verb_superset2=all_synsets(noun2,verb2)
```

Here noun_superset1 contains all the different categories of nouns in novel 1 and verb_superset1 contains all the categories of verbs.

Eg.

```
print(noun_superset1)

['noun.event', 'noun.time', 'noun.act', 'noun.act', 'noun.act', 'noun.location',

len(noun_superset1)

135183
```

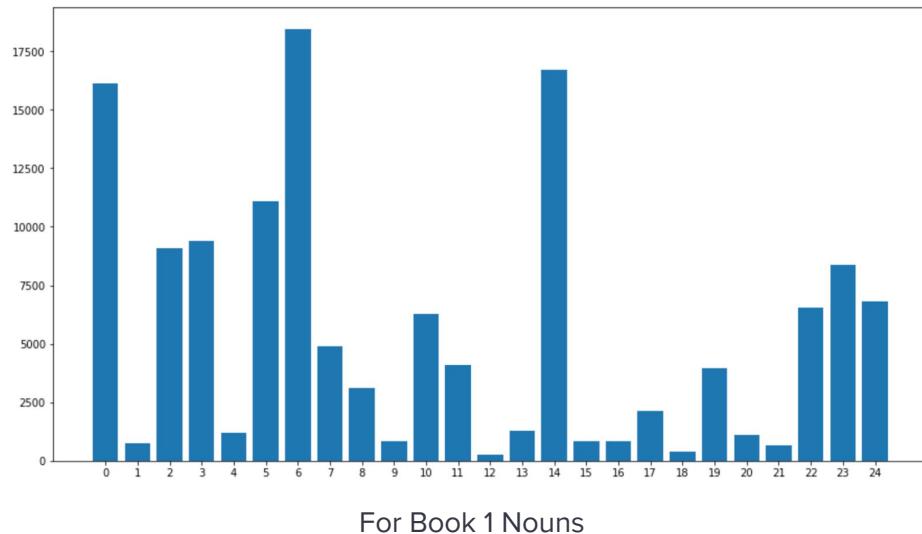
Hence there are 13.5k elements in the list.

Plotting the histograms:

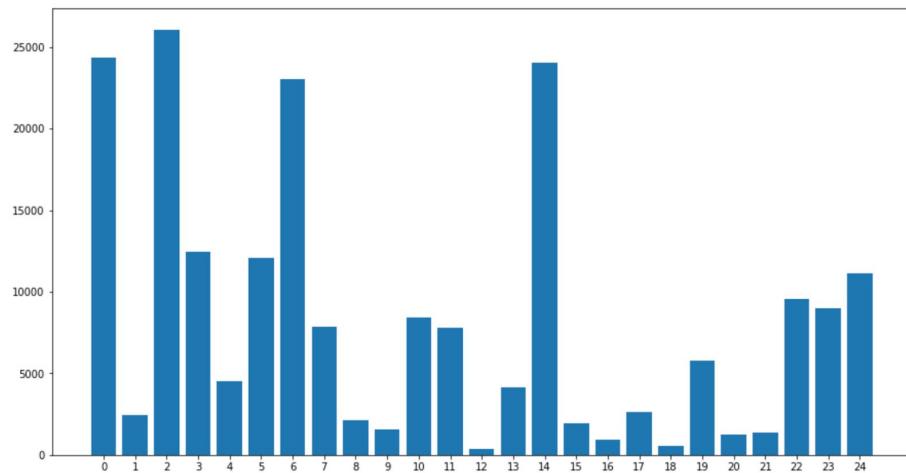
We have used numpy to count the frequency of each type of noun and verb out of 25 categories of nouns and 15 categories of verbs from both the novels.

```
import numpy as np
labels, counts = np.unique(noun_superset1, return_counts=True)
import matplotlib.pyplot as plt
ticks = range(len(counts))
plt.figure(figsize=(15,8))
plt.bar(ticks, counts, align='center')
plt.xticks(ticks, range(len(labels)))
labels, counts = np.unique(noun_superset2, return_counts=True)
ticks = range(len(counts))
plt.figure(figsize=(15,8))
plt.bar(ticks, counts, align='center')
plt.xticks(ticks, range(len(labels)))
```

After plotting the graphs we get the following plots where Y axis is counts and x axis are categories:



For Book 1 Nouns



For Book 2 Nouns

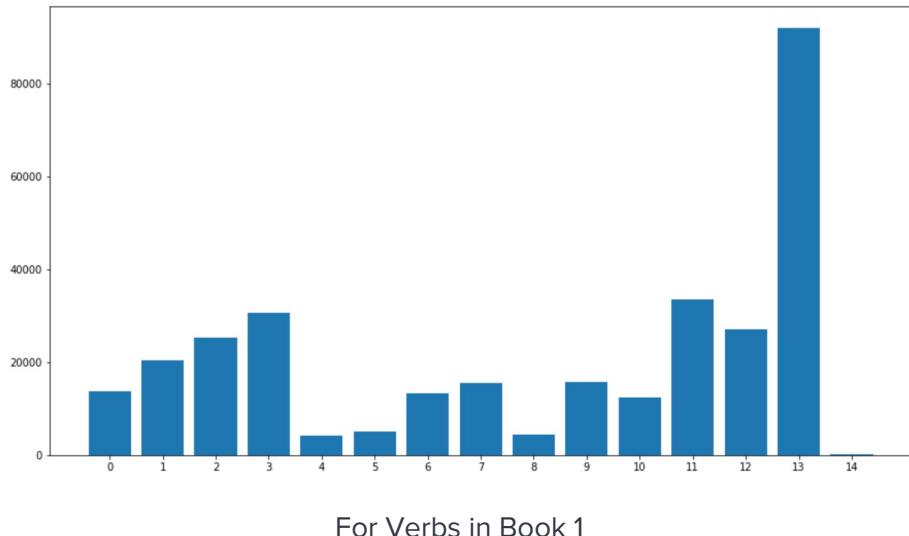
The categories are numbered as 0-24 in the order:

```
print(labels)

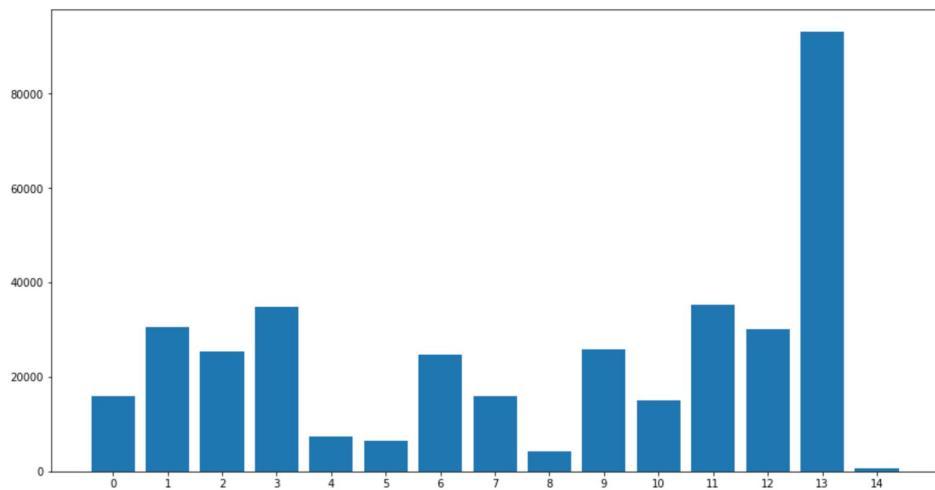
['noun.act' 'noun.animal' 'noun.artifact' 'noun.attribute' 'noun.body'
 'noun.cognition' 'noun.communication' 'noun.event' 'noun.feeling'
 'noun.food' 'noun.group' 'noun.location' 'noun.motive' 'noun.object'
 'noun.person' 'noun.phenomenon' 'noun.plant' 'noun.possession'
 'noun.process' 'noun.quantity' 'noun.relation' 'noun.shape' 'noun.state'
 'noun.substance' 'noun.time']
```

Here labels are arranged in the order of hierarchy as given in wordnet categories of nouns.

Similarly we get the following plots for Verbs:



For Verbs in Book 1



For Verbs in Book 2

And the labels are numbered as 0-14 in the following order.

```
['verb.body' 'verb.change' 'verb.cognition' 'verb.communication'  
 'verb.competition' 'verb.consumption' 'verb.contact' 'verb.creation'  
 'verb.emotion' 'verb.motion' 'verb.perception' 'verb.possession'  
 'verb.social' 'verb.stative' 'verb.weather']
```

Named Entity Recognition

1. Get the entities involved in each of the novels.

To perform Named Entity Recognition in both the novels we have used Spacy. SpaCy's named entity recognition has been trained on the OntoNotes 5 corpus and it supports the following entity types:

TYPE	DESCRIPTION
PERSON	People, including fictional.
NORP	Nationalities or religious or political groups.
FAC	Buildings, airports, highways, bridges, etc.
ORG	Companies, agencies, institutions, etc.
GPE	Countries, cities, states.
LOC	Non-GPE locations, mountain ranges, bodies of water.
PRODUCT	Objects, vehicles, foods, etc. (Not services.)
EVENT	Named hurricanes, battles, wars, sports events, etc.
WORK_OF_ART	Titles of books, songs, etc.
LAW	Named documents made into laws.
LANGUAGE	Any named language.
DATE	Absolute or relative dates or periods.
TIME	Times smaller than a day.
PERCENT	Percentage, including "%".
MONEY	Monetary values, including unit.
QUANTITY	Measurements, as of weight or distance.
ORDINAL	"first", "second", etc.
CARDINAL	Numerals that do not fall under another type.

The Spacy uses token-level entity annotation using the BILUO tagging scheme to describe the entity boundaries. Where,

TAG	DESCRIPTION
B EGIN	The first token of a multi-token entity.
I N	An inner token of a multi-token entity.
L AST	The final token of a multi-token entity.
U NIT	A single-token entity.
O UT	A non-entity token.

First we import spacy and get the entities involved in both the novels using the methods described in the library.

```
import spacy
from spacy import displacy
from collections import Counter
import en_core_web_sm
nlp = en_core_web_sm.load()
doc1 = nlp(book1_text)
doc2 = nlp(book2_text)
print("there are total "+str(len(doc1.ents))+" entities in book 1 and "+str(len(doc2.ents))+" in book 2")
there are total 3322 entities in book 1 and 2688 in book 2

print([(x, x.ent_iob_) for x in doc1])
[('start', 'O'), ('of', 'O'), ('this', 'O'), ('project', 'O'), ('gutenberg', 'O'), ('ebook', 'O'),

print([(x, x.ent_iob_) for x in doc2])
[('start', 'O'), ('of', 'O'), ('this', 'O'), ('project', 'O'), ('gutenberg', 'O'), ('ebook', 'O'),
```

As we can see the entities are annotated using the BILUO entity scheme.

3. Get the entities which are annotated as Person,Organization and Location by Spacy.

We have used the following function on the entities returned by spacy to collect the Person, Organization and Location entities in each of the novels respectively. The ent_type function returns the type of entity annotated by Spacy and hence return lists containing the above types of entities.

```

def entity_recognition(text):
    doc=nlp(text)
    person=[]
    org=[]
    location=[]
    for X in doc:
        if (X.ent_type_=='PERSON') and X.text not in person:
            person.append(X.text)
        if (X.ent_type_=='ORG')and X.text not in org:
            org.append(X.text)
        if ((X.ent_type_=='LOC') or (X.ent_type_=='GPE')) and X.text not in location:
            location.append(X.text)
    return person,org,location

```

Now collecting these entities from both books:

```

person1,org1,location1=entity_recognition(book1_text)
person2,org2,location2=entity_recognition(book2_text)
print("number of person entities in book 1 and book 2 respectively are "+str(len(person1))+" and "+str(len(person2)))
print("number of organization entities in book 1 and book 2 respectively are "+str(len(org1))+" and "+str(len(org2)))
print("number of location entities in book 1 and book 2 respectively are "+str(len(location1))+" and "+str(len(location2)))

number of person entities in book 1 and book 2 respectively are 175 and 212
number of organization entities in book 1 and book 2 respectively are 46 and 82
number of location entities in book 1 and book 2 respectively are 37 and 77

```

Each of these lists contain the corresponding entities.

Counting the number of occurrences of names, locations, and organizations in Book 1, we get:

```

x = freq(person1)
print(sorted(x.items(), key = lambda kv:(kv[1], kv[0]),reverse=True))

[('elizabeth', 623), ('jane', 284), ('bingley', 175), ('s', 138), ('bennet', 109), ('lizzy', 83), ('darcy'

x = freq(location1)
print(sorted(x.items(), key = lambda kv:(kv[1], kv[0]),reverse=True))

[('lydia', 136), ('london', 52), ('netherfield', 30), ('lucas', 15), ('kitty', 12), ('us', 8), ('brighton'

x = freq(org1)
print(sorted(x.items(), key = lambda kv:(kv[1], kv[0]),reverse=True))

[('wickham', 13), ('house', 12), ('the', 11), ('lambton', 9), ('s', 8), ('party', 5), ('netherfield', 5),

```

Performance of The Entity Recognition model on the dataset:

To measure the performance of the model on the dataset, we collected 10 random samples/passages from the novel and labeled them manually for these entities. After Labeling we compared them with the Labels assigned to them by Spacy's Entity Recognition Algorithm.

We processed the samples and labels as lists and then passed each of the sample to the algorithm for Entity Recognition. Total 10 such samples are selected and labeled.

```
sample_book_1_1='georgiana have the highest opinion
sample_book_1_2='i believe i think only of _you_. "
sample_book_1_3=' of this marriage to her ladyship 1
sample_book_1_4='catherine would not come in again a

hand_labeled_book_1_1=['PER','O','O','O','O','O','O',
hand_labeled_book_1_2=['O','O','O','O','O','O','O',
hand_labeled_book_1_3=['O','O','O','O','O','O','O',
hand_labeled_book_1_4=['PER','O','O','O','O','O','O']
```

After passing the samples to the spacy's algorithm we collect the entities labeled by :

```
labels_book_1_1=([(X.text) for X in nlp(sample_book_1_1).ents])
labels_book_1_2=([(X.text) for X in nlp(sample_book_1_2).ents])
labels_book_1_3=([(X.text) for X in nlp(sample_book_1_3).ents])
labels_book_1_4=[[(X.text) for X in nlp(sample_book_1_4).ents]]
```

To Calculate the performance metric we have used precision,recall and the f1 scores of the predictions.

To Calculate these metrics, we created a confusion matrix and then calculated the above scores from it:

It was a complex task as the confusion metrics couldnt be computed directly from the predicted_entities and true_entities.

```
from typing import List, Dict, Sequence

class Metrics:
    def __init__(self, sents_true_labels: Sequence[Sequence[Dict]], sents_pred_labels: Sequence[Sequence[Dict]]):
        self.sents_true_labels = sents_true_labels
        self.sents_pred_labels = sents_pred_labels
        self.types = set(entity['type'] for sent in sents_true_labels for entity in sent)
        self.confusion_matrices = {type: {'TP': 0, 'TN': 0, 'FP': 0, 'FN': 0} for type in self.types}
        self.scores = {type: {'p': 0, 'r': 0, 'f1': 0} for type in self.types}

    def cal_confusion_matrices(self) -> Dict[str, Dict]:
        """Calculate confusion matrices for all sentences."""
        for true_labels, pred_labels in zip(self.sents_true_labels, self.sents_pred_labels):
            for true_label in true_labels:
                entity_type = true_label['type']
                prediction_hit_count = 0
                for pred_label in pred_labels:
                    if pred_label['type'] != entity_type:
                        continue
                    if pred_label['start_idx'] == true_label['start_idx'] and pred_label['end_idx'] == true_label['end_idx'] and pred_label['text'] == true_label['text']: # TP
                        self.confusion_matrices[entity_type]['TP'] += 1
                        prediction_hit_count += 1
                    elif ((pred_label['start_idx'] == true_label['start_idx']) or (pred_label['end_idx'] == true_label['end_idx'])) and pred_label['text'] != true_label['text']:
                        self.confusion_matrices[entity_type]['FP'] += 1
                        prediction_hit_count += 1
                    else:
                        self.confusion_matrices[entity_type]['FN'] += 1
                        prediction_hit_count += 1
                if prediction_hit_count != 1: # FN, model cannot make a prediction for true_label
                    self.confusion_matrices[entity_type]['FN'] += 1
                prediction_hit_count = 0 # reset to default
```

```

def cal_scores(self) -> Dict[str, Dict]:
    """Calculate precision, recall, f1."""
    confusion_matrices = self.confusion_matrices
    scores = {type: {'p': 0, 'r': 0, 'f1': 0} for type in self.types}

    for entity_type, confusion_matrix in confusion_matrices.items():
        if confusion_matrix['TP'] == 0 and confusion_matrix['FP'] == 0:
            scores[entity_type]['p'] = 0
        else:
            scores[entity_type]['p'] = confusion_matrix['TP'] / (confusion_matrix['TP'] + confusion_matrix['FP'])

        if confusion_matrix['TP'] == 0 and confusion_matrix['FN'] == 0:
            scores[entity_type]['r'] = 0
        else:
            scores[entity_type]['r'] = confusion_matrix['TP'] / (confusion_matrix['TP'] + confusion_matrix['FN'])

        if scores[entity_type]['p'] == 0 or scores[entity_type]['r'] == 0:
            scores[entity_type]['f1'] = 0
        else:
            scores[entity_type]['f1'] = 2*scores[entity_type]['p']*scores[entity_type]['r'] / (scores[entity_type]['p']+scores[entity_type]['r'])
    self.scores = scores

```

Using the above code snippet we will be able to calculate the scores straight from the predicted entities and true entities.

To ensure that we are only computing the PER,ORG,LOC,GPE (Person,organization and location) entities, we mark other entities as O and proceed with the performance evaluation.

```

for x in range(len(labels_book_1_1)):
    if (labels_book_1_1[x]== '') or (not in ['ORG', 'LOC', 'GPE', 'PER']) :
        labels_book_1_1[x]='O'
for x in range(len(labels_book_1_2)):
    if [labels_book_1_2[x]== ')] or (not in ['ORG', 'LOC', 'GPE', 'PER']):
        labels_book_1_2[x]='O'
for x in range(len(labels_book_1_3)):
    if (labels_book_1_3[x]== '') or (not in ['ORG', 'LOC', 'GPE', 'PER']):
        labels_book_1_3[x]='O'
for x in range(len(labels_book_1_4)):
    if (labels_book_1_4[x]== '') or (not in ['ORG', 'LOC', 'GPE', 'PER']):
        labels_book_1_4[x]='O'

```

After evaluating the labels in all of the samples from book 1 we get:

	precision	recall	f1-score	support
PER	0.77	0.75	0.76	72
ORG	0.25	0.25	0.25	4
LOC	0.78	0.80	0.79	12
GPE	0.82	0.87	0.84	25
O	0.96	0.94	0.99	554
avg/total	0.66	0.72	0.69	667

And Similarly performing the above steps for book 2 we get:

	precision	recall	f1-score	support
PER	0.73	0.75	0.76	67
ORG	0.5	0.5	0.5	6
LOC	0.66	0.72	0.69	20
GPE	0.82	0.87	0.85	17
O	0.94	0.96	0.95	474
avg/total	0.75	0.76	0.76	584

Hence we get average f1 score of 0.69 in first book and 0.76 in second book after evaluation.

Relationship Extraction

To perform Relation Extraction , we use `extract_rels` method of `nltk.sem.relextract`

Once named entities have been identified in a text, we then want to extract the relations that exist between them. As indicated earlier, we will typically be looking for relations between specified types of named entity. One way of approaching this task is to initially look for all triples of the form (X, a, Y) , where X and Y are named entities of the required types, and a is the string of words that intervenes between X and Y . We can then use regular expressions to pull out just those instances of a that express the relation that we are looking for.

```
import re
from nltk import ne_chunk, pos_tag, word_tokenize
from nltk.sem.relextract import extract_rels, rtuple
nltk.download('maxent_ne_chunker')
nltk.download('words')
```

1. Person - Location Relationship Extraction

We are able to extract 5 person-location relationships using the following regular expression

```
text = BookText(url1)

BELONG = re.compile(r'.*\bin|from|belonged|lived\b.*')

sentences = nltk.sent_tokenize(text)
tokenized_sentences = [nltk.word_tokenize(sentence) for sentence in sentences]
tagged_sentences = [nltk.pos_tag(sentence) for sentence in tokenized_sentences]

for i,sent in enumerate(tagged_sentences):
    sent = ne_chunk(sent)
    rels = extract_rels('PER', 'GPE', sent, corpus = 'ace', pattern = BELONG, window = 10)
    for rel in rels:
        print(rtuple(rel))

[PER: 'elizabeth/NNP'] 'lived/VBN in/IN' [GPE: 'london/NNP']
[PER: 'jane/NNP'] 'lived/VBN near/IN' [GPE: 'neitherfield/NNP']
[PER: 'bingley/NNP'] 'is/VBZ from/IN' [GPE: 'scotland/NNP']
[PER: 'elizabeth/NNP'] 'belonged/VBD to/IN' [GPE: 'london/NNP']
[PER: 'jane/NNP'] 'was/VBD now/RB in/IN' [GPE: 'brighton/NNP']
```

2. Person-Person Relationship Extraction (Relationship b/w characters)

We are able to extract 4 person-person relationships using the following regular expression

```
RELATIONS = re.compile(r'.*\bmother|father|sister|brother|aunt|uncle\b.*')

for i,sent in enumerate(tagged_sentences):
    sent = ne_chunk(sent)
    rels = extract_rels('PER', 'PER', sent, corpus = 'ace', pattern = RELATIONS, window = 10)
    for rel in rels:
        print(rttuple(rel))

[PER: 'elizabeth/NNP'] 'mother/NN' [PER: 'marie/NNP']
[PER: 'jane/NNP'] 'lived/VBN with/IN her/PRP$ father/NN' [PER: 'wickham/NNP']
[PER: 'elizabeth/NNP'] 'spent/NN most/JJS of/IN her/PRP$ childhood/NN with/IN aunt/NN' [PER: 'lily/NNP']
[PER: 'wickham/NNP'] 'was/VBD often/RB beaten/VBN by/IN uncle/NN' [PER: 'lucas/NNP']
```

3. Person-Organization Relationship

We are able to extract 3 organization relationships using the following regular expression

```
ORG = re.compile(r'.*\bwork|of|in\b.*')

for i,sent in enumerate(tagged_sentences):
    sent = ne_chunk(sent)
    rels = extract_rels('PER', 'ORG', sent, corpus = 'ace', pattern = ORG, window = 10)
    for rel in rels:
        print(rttuple(rel))

[PER: 'jane/NNP'] 'became/VBD the/DT ceo/NN of/IN' [ORG: 'clapham/NNP']
[PER: 'bingley/NNP'] 'loved/VBD the/DT work/NN of/IN' [ORG: 'phillips/NNP']
[PER: 'bennet/NNP'] 'was/VBD involved/VBN in/IN' [ORG: 'lambton/NNP']
```

Inferences :

- Elizabeth lived in London at some point of time
- Jane lived near netherfield at some point of time
- Jane went to Brighton in the story plot
- Wickham was Jane's Father
- Lucas was Wickham's Uncle
- Lily was Elizabeth's Aunt, and Elizabeth spent most of her childhood with her
- Jane was the CEO of Clapham
- Mrs. Bennet had some role in Lambton

Conclusion

We have learnt how to perform Semantic analysis, POS-Tagging, Named Entity Recognition, Performance evaluation in NLP and Extracting Entity relationships from raw text data through NLP and have answered the questions in Project Round 2 successfully.