# N-Grams

April 28, 2024

```
<h1>Natural Language Processing</h1>
Assignment 02
<h3>General Information:</h3>
<p>Please do not add or delete any cells. Answers belong into the corresponding cells (below th
<p>Code cells where you are supposed to give your answer often include the line  ```raise NotIm
<h3>Submission:</h3>
<p>Please submit your notebook via the web interface (in the main view -> Assignments -> Submit
<h3>Group Work:</h3>
<p>You are allowed to work in groups of up to three people. Please enter the UID (your username
<h3>Questions about the Assignment:</h3>
<p>If you have questions about the assignment please post them in the LEA forum before the deac
```

[ ]:
```
'''
Group Work:
Enter the UID of each team member into the variables. This is your **LEA␣
 ↪username**!
If you work alone please leave the second variable empty.
'''
member1 = 'mfarra2s'
member2 = ''
member3 = ''
```

## 1 Bigram Language Model

We want to build a count based bigram language model based on movie scripts.

In the next cell the movie scripts are read into the variables `sents` and `words` for the movies *Iron Man 2*, *Iron Man 3*, *Spider-Man Homecoming*.

[2]:
```
import pickle

def load_data(path):
    with open(path, "rb") as f:
        sents = pickle.loads(f.read())
        words = [word for sent in sents for word in sent]
    return sents, words
```

```
iron_man2_sents, iron_man2_words = load_data("/srv/shares/NLP/datasets/marvel/
 ↪iron_man_2.pkl")
iron_man3_sents, iron_man3_words = load_data("/srv/shares/NLP/datasets/marvel/
 ↪iron_man_3.pkl")
spider_man_sents, spider_man_words = load_data("/srv/shares/NLP/datasets/marvel/
 ↪spider_man_homecoming.pkl")

spider_man_words
```

[2]:
```
['[',
 'Adrian',
 'Toomes',
 'and',
 'his',
 'coworker',
 ',',
 'Phineas',
 'Mason',
 ',',
 'are',
 'studying',
 'a',
 'child',
 "'s",
 'drawing',
 'of',
 'the',
 'Avengers',
 '.',
 ']',
 'Toomes',
 ':',
 'Things',
 'are',
 'never',
 'gon',
 'na',
 'be',
 'the',
 'same',
 'now',
 '.',
 'I',
 'mean',
 ',',
 'look',
 'at',
```

```
'this',
'.',
'You',
'got',
'aliens',
'.',
'You',
'got',
'big',
'green',
'guys',
'tearing',
'down',
'buildings',
'.',
'When',
'I',
'was',
'a',
'kid',
',',
'I',
'used',
'to',
'draw',
'cowboys',
'and',
'Indians',
'.',
'Mason',
':',
'Actually',
',',
'it',
"'s",
'Native',
'American',
',',
'but',
'whatever',
'.',
'Toomes',
':',
'Yeah',
'.',
'Tell',
'you',
```

```
'what',
',',
'though',
'.',
'It',
'ai',
"n't",
'bad',
',',
'is',
'it',
'?',
'[',
'Toomes',
'squints',
'at',
'the',
'drawing',
'and',
'Mason',
'nods',
'.',
']',
'Mason',
':',
'No',
'.',
'Yeah',
'.',
'Kid',
"'s",
'got',
'a',
'future',
'.',
'Toomes',
':',
'Yeah',
',',
'well',
'…',
'We',
"'ll",
'see',
',',
'I',
'guess',
```

```
'.',
'[',
'Toomes',
'looks',
'up',
'at',
'the',
'damaged',
'Avengers',
'Tower',
'.',
'Helicopters',
'pass',
'overhead',
'.',
'Scaffolding',
'covers',
'the',
'tower',
"'s",
'lower',
'floors',
'.',
'A',
'roving',
'view',
'sends',
'us',
'into',
'a',
'ruined',
'building',
'across',
'the',
'street',
'.',
']',
'[',
'A',
'clean',
'-',
'up',
'crew',
'works',
'around',
'a',
'giant',
```

```
'deceased',
'Chitauri',
'alien',
'creature',
'with',
'pointed',
'teeth',
'.',
'Alien',
'artifacts',
'lie',
'among',
'the',
'rubble',
'.',
'Walking',
'through',
'the',
'site',
',',
'Toomes',
'gives',
'a',
'worker',
'a',
'thumbs',
'up',
'.',
'He',
'turns',
'to',
'Herman',
'Schultz',
',',
'who',
'is',
'one',
'of',
'his',
'workers',
'.',
']',
'Toomes',
':',
'No',
',',
'hey',
```

```
'!',
'Uh',
'-',
'uh',
'!',
'You',
'ca',
"n't",
'saw',
'through',
'that',
'stuff',
'.',
'These',
'alien',
'bastards',
'are',
'tough',
'.',
'You',
'got',
'ta',
'use',
'the',
'stuff',
'they',
'use',
'.',
'[',
'He',
'picks',
'up',
'an',
'alien',
'object',
'from',
'the',
'ground',
'and',
'uses',
'it',
'as',
'a',
'tool',
'to',
'break',
'down',
```

```
'the',
'Chitauri',
'chariot',
'.',
']',
'Toomes',
':',
'See',
'?',
'Schultz',
':',
'All',
'right',
'.',
'Toomes',
':',
'All',
'right',
'.',
'(',
'to',
'Brice',
')',
'Oh',
',',
'hey',
'!',
'Glad',
'you',
'could',
'join',
'us',
'.',
'Afternoon',
'.',
'Brice',
':',
'Yeah',
'.',
'My',
'alarm',
'did',
"n't",
'go',
'off',
'.',
'Toomes',
```

```
':',
'Yeah',
',',
'yeah',
',',
'yeah',
',',
'your',
'alarm',
'.',
'Look',
',',
'just',
'go',
'stack',
'that',
'armor',
'plating',
'like',
'I',
'asked',
'you',
'.',
'This',
'is',
'a',
'huge',
'deal',
'for',
'us',
'.',
'[',
'Anne',
'Marie',
'Hoag',
',',
'the',
'director',
'of',
'the',
'Department',
'of',
'Damage',
'Control',
',',
'walks',
'into',
```

```
'the',
'salvage',
'site',
'with',
'her',
'crew',
'.',
']',
'Anne',
'Marie',
'Hoag',
':',
'Attention',
',',
'please',
'!',
'In',
'accordance',
'with',
'Executive',
'Order',
'396B',
',',
'all',
'post',
'-',
'battle',
'cleanup',
'operations',
'are',
'now',
'under',
'our',
'jurisdiction',
'.',
'Thank',
'you',
'for',
'your',
'service',
'.',
'We',
"'ll",
'take',
'it',
'from',
'here',
```

```
'.',
'Toomes',
':',
'Who',
'the',
'hell',
'are',
'you',
'?',
'DODC',
'Agent',
':',
'Qualified',
'personnel',
'.',
'Toomes',
':',
'Look',
',',
'I',
'have',
'a',
'city',
'contract',
'to',
'salvage',
'all',
'this',
',',
'okay',
',',
'with',
'the',
'city',
',',
'so-',
'Anne',
'Marie',
'Hoag',
':',
'I',
'apologize',
',',
'Mr.',
'Toomes',
',',
'but',
```

```
'all',
'salvage',
'operations',
'are',
'now',
'under',
'our',
'jurisdiction',
'.',
'Please',
'turn',
'over',
'any',
'and',
'all',
'exotic',
'materials',
'that',
'you',
"'ve",
'collected',
',',
'or',
'you',
'will',
'be',
'prosecuted',
'.',
'[',
'The',
'workers',
'look',
'puzzled',
'.',
'A',
'worker',
'slips',
'an',
'alien',
'artifact',
'that',
'looks',
'like',
'a',
'power',
'source',
'into',
```

```
'his',
'pocket',
'unnoticed',
'.',
']',
'Toomes',
':',
"Ma'am",
',',
'what',
'am',
'I-',
'Please',
'.',
'Come',
'here',
'.',
'Hey',
',',
'lady',
',',
'come',
'on',
'.',
'Look',
'…',
'I',
'bought',
'trucks',
'for',
'this',
'job',
'.',
'I',
'brought',
'in',
'a',
'whole',
'new',
'crew',
'.',
'These',
'guys',
'have',
'a',
'family',
'.',
```

```
'I',
'have',
'a',
'family',
'.',
'I',
"'m",
'all',
'in',
'on',
'this',
'.',
'I',
'could',
'lose',
'my',
'house',
'.',
'Anne',
'Marie',
'Hoag',
':',
'I',
"'m",
'sorry',
',',
'sir',
'.',
'There',
"'s",
'nothing',
'I',
'can',
'do',
'.',
'[',
'Toomes',
'is',
'left',
'to',
'stare',
'at',
'her',
'back',
'as',
'she',
'leaves',
```

```
'.',
'Behind',
'him',
',',
'a',
'Damage',
'Control',
'Agent',
'speaks',
'up',
'.',
']',
'DODC',
'Agent',
':',
'Maybe',
'next',
'time',
',',
'do',
"n't",
'over',
'extend',
'yourself',
'.',
'[',
'Toomes',
'looks',
'around',
'and',
'grins',
'.',
']',
'Toomes',
':',
'What',
"'d",
'you',
'say',
'?',
'[',
'He',
'looks',
'around',
'at',
'his',
'crew',
```

```
'of',
'workers',
'.',
'Brice',
'whistles',
'.',
']',
'Toomes',
':',
'Yeah',
',',
'he',
"'s",
'right',
'.',
'I',
'overextended',
'myself',
'.',
'[',
'Suddenly',
',',
'he',
'punches',
'the',
'agent',
'.',
'The',
'agents',
'point',
'their',
'guns',
'at',
'him',
'.',
']',
'Worker',
':',
'Do',
"n't",
'do',
'it',
'.',
'Anne',
'Marie',
'Hoag',
':',
```

```
'Put',
'them',
'down',
'.',
'[',
'The',
'agents',
'lower',
'their',
'guns',
'.',
']',
'Anne',
'Marie',
'Hoag',
':',
'If',
'you',
'have',
'a',
'grievance',
',',
'you',
'may',
'take',
'it',
'up',
'with',
'my',
'superiors',
'.',
'Toomes',
':',
'Your',
'superiors',
'.',
'Who',
'the',
'hell',
'are',
'they',
'?',
'[',
'We',
'see',
'a',
'TV',
```

```
'screen',
'playing',
'the',
'news',
'about',
'Tony',
'Stark',
'and',
'his',
'contract',
'with',
'Damage',
'Control',
'.',
'Toomes',
'watches',
'the',
'TV',
'with',
'an',
'angry',
'look',
'on',
'his',
'face',
'.',
']',
'News',
'Anchor',
':',
'A',
'joint',
'venture',
'between',
'Stark',
'Industries',
'and',
'the',
'federal',
'government',
',',
'the',
'Department',
'of',
'Damage',
'Control',
'will',
```

```
'oversee',
'the',
'collection',
'and',
'storage',
'of',
'alien',
'and',
'other',
'exotic',
'materials',
'.',
'Schultz',
':',
'So',
'now',
'the',
'assholes',
'who',
'made',
'this',
'mess',
'are',
'being',
'paid',
'to',
'clean',
'it',
'up',
'.',
'Mason',
':',
'Yeah',
',',
'it',
'’s',
'all',
'rigged',
'.',
'[',
'Mason',
'is',
'tinkering',
'with',
'the',
'alien',
'power',
```

```
'source',
'that',
'one',
'of',
'the',
'workers',
'stole',
'from',
'the',
'salvage',
'site',
'earlier',
'that',
'day',
'.',
']',
'News',
'Anchor',
':',
'Experts',
'estimate',
'there',
'are',
'over',
'fifteen',
'hundred',
'tons',
'of',
'exotic',
'material',
'scattered',
'throughout',
'the',
'tri',
'-',
'state',
'area',
'.',
'[',
'The',
'glowing',
'alien',
'artifact',
'is',
'now',
'connected',
'to',
```

```
'a',
'motor',
'with',
'wires',
'.',
'The',
'blades',
'on',
'the',
'motor',
'start',
'to',
'spin',
'and',
'the',
'machine',
'floats',
'off',
'the',
'table',
'.',
'One',
'of',
'the',
'workers',
'pulls',
'off',
'a',
'tarpaulin',
'sheet',
'covering',
'a',
'large',
'piece',
'of',
'Chitauri',
'artifact',
',',
'revealing',
'a',
'dozen',
'of',
'glowing',
'Chitauri',
'energy',
'cores',
'.',
```

```
']',
'Worker',
':',
'Hey',
',',
'chief',
'!',
'We',
'still',
'have',
'another',
'load',
'from',
'yesterday',
'.',
'We',
'’re',
'supposed',
'to',
'turn',
'this',
'in',
',',
'right',
'?',
'Brice',
':',
'I',
'ai',
'n’t',
'hauling',
'it',
'.',
'Mason',
':',
'It',
'’s',
'too',
'bad',
'.',
'We',
'could',
'have',
'made',
'some',
'pretty',
'cool',
```

```
 'stuff',
 'from',
 'all',
 'that',
 'alien',
 'junk',
 '.',
 '[',
 'Toomes',
 'stares',
 'at',
 'the',
 'truck',
 'full',
 'of',
 'alien',
 'items',
 'and',
 'makes',
 'up',
 'his',
 'mind',
 …]
```

[ ]:
```
import glob

glob.glob("/srv/shares/NLP/datasets/marvel/*.pkl")
```

### 1.1 1.1) Statistics [4 Points]

Please calculate the number of types and tokens for the movie *Spider-Man* and save the values in the variables `types` and `tokens`.

[4]:
```
types = 0
tokens = 0
# YOUR CODE HERE
types = len(set(spider_man_words))
tokens = len(spider_man_words)
# raise NotImplementedError()

print('The script for Spider-Man Homecoming consists of {} tokens and {} types.
 ↪'.format(
    tokens,
    types
))
```

```
The script for Spider-Man Homecoming consists of 39530 tokens and 4115 types.
```

[ ]:
```
# This is a test cell, please ignore it!
```

## 1.2 1.2) Heap's Law

Let us validate Heap's law from the first chapter we read:

$|V| = k * N^{\beta}$

### 1.2.1 1.2.1) Empirical Study [8 Points]

We first want to plot the relationship between types and tokens for the script *Spider-Man Homecoming*.

For this you should fill the lists `number_of_types` and `number_of_tokens` with the corresponding values.

So we want to investigate how many types we have after 1 token, 2 tokens, 3 tokens until we have read all the words from the book.

*Example:*

- `number_of_tokens: [1, 2, 3, ..., 16, 17, 18, ...]`
- `number_of_types: [1, 2, 3, ..., 13, 14, 14, ...]`

[6]:
```
number_of_tokens = []
number_of_types = []

# YOUR CODE HERE
for i in range(1,tokens+1):
    number_of_tokens.append(i)
    number_of_types.append(len(set(spider_man_words[0:i])))

# raise NotImplementedError()

for i in [10, 100, 1000, 10000]:
    print('After reading {} tokens we found {} types.'.format(
        number_of_tokens[i - 1], number_of_types[i - 1]
    ))
```

```
After reading 10 tokens we found 9 types.
After reading 100 tokens we found 68 types.
After reading 1000 tokens we found 395 types.
After reading 10000 tokens we found 1929 types.
```

[ ]:
```

```

### 1.2.2 1.2.2) Plot [10 Points]

Please plot your findings:

- x-Axis: Number of tokens

- y-Axis: Number of types

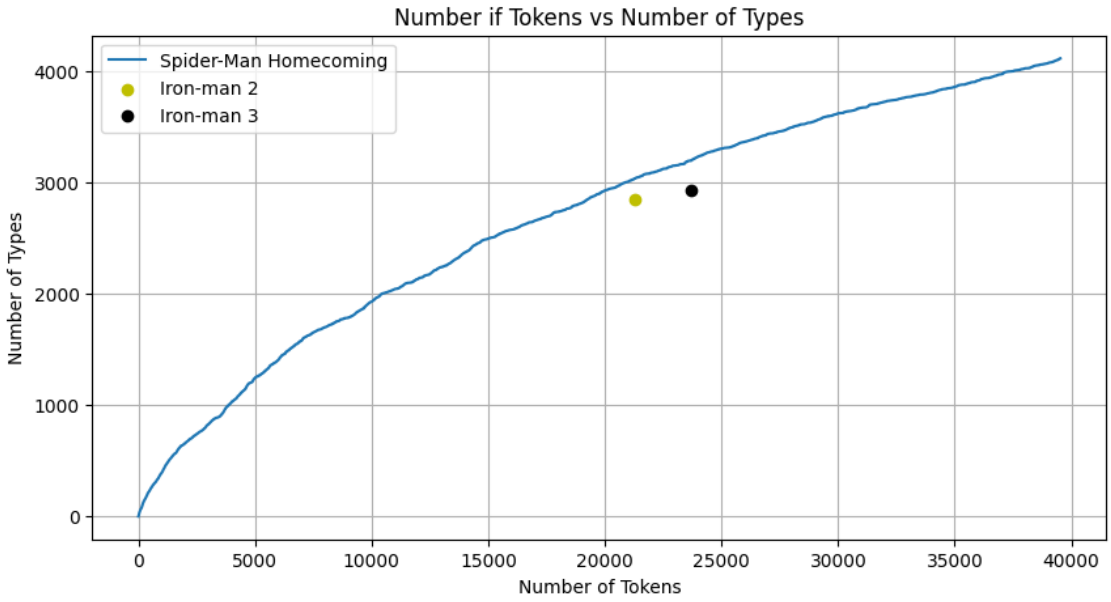
Make sure your plot has a grid, a legend, a title and x- and y-label.

Add the values for the three movies **Iron Man 2** and **Iron Man 3** to the plot as a single point (total number of tokens, total number of types)

[32]:
```
import matplotlib.pyplot as plt

plt.figure(figsize=(10, 5))

# YOUR CODE HERE
plt.plot(number_of_tokens,number_of_types, label='Spider-Man Homecoming')
plt.scatter(len(iron_man2_words),len(set(iron_man2_words)), c='y',␣
 ↪label='Iron-man 2')
plt.scatter(len(iron_man3_words),len(set(iron_man3_words)), c='k', ␣
 ↪label='Iron-man 3')
plt.title('Number if Tokens vs Number of Types')
plt.grid(True)
plt.xlabel('Number of Tokens')
plt.ylabel('Number of Types')
plt.legend()
plt.show()
```




### 1.2.3 1.2.3) Estimate parameters $k$ and $\beta$ [8 points]

We want to estimate the parameters $k$ and $\beta$ for Heap's law based on our movie.

Use the function `curve_fit` from `scipy.optimize` with the previously calculated lists. Save your

solution in the variables `k` and `beta`.

`curve_fit` takes in three arguments, the function that relatex x values to y values together with its parameters, the observed x-values and the observed y-values. It return popt (the optimal parameters) and pcov (how well they fit).

[29]:
```
from scipy.optimize import curve_fit

def func(x, k, beta):
    return k * x**beta

k = 0
beta = 0

# YOUR CODE HERE

params, covariance = curve_fit(func, number_of_tokens, number_of_types)

k, beta = params
# raise NotImplementedError()

print('For the movie Spider-Man we estimate k = {:.2f} and beta = {:.2f}'.
 ↪format(
    k,
    beta
))
```

```
For the movie Spider-Man we estimate k = 10.23 and beta = 0.57
```

[ ]:
```

```

### 1.2.4 1.2.4) Combined plot [10 Points]

In our Marvel corpus we have the following movies:

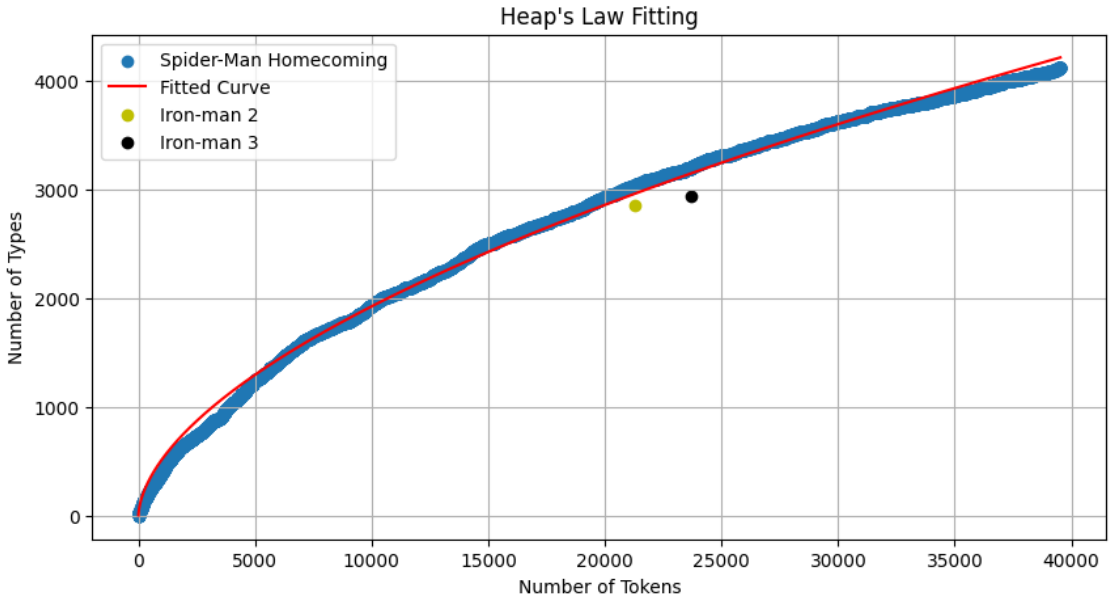
- Iron Man 2
- Iron Man 3
- Spider-Man Homecoming

Plot the number of types and tokens for each movie as a point (total number of types and tokens) together with the function $|V| = kN^{\beta}$ with your estimated parameters.

[33]:
```
import matplotlib.pyplot as plt

plt.figure(figsize=(10, 5))
# YOUR CODE HERE
plt.scatter(number_of_tokens, number_of_types, label='Spider-Man Homecoming')
plt.plot(number_of_tokens, func(number_of_tokens, *params), color='r',␣
 ↪label='Fitted Curve')
```

```
plt.scatter(len(iron_man2_words),len(set(iron_man2_words)), c='y',␣
 ↪label='Iron-man 2')
plt.scatter(len(iron_man3_words),len(set(iron_man3_words)), c='k', ␣
 ↪label='Iron-man 3')
plt.xlabel('Number of Tokens')
plt.ylabel('Number of Types')
plt.title("Heap's Law Fitting")
plt.grid(True)
plt.legend()
plt.show()
```




### 1.3 2.1) Bigram Model [50 Points]

We now want to build a bigram language model from the movie *Spider-Man Homecoming*.

For this you should use the class given in the next cell.

1. Read in the sentences from the movie *Spider-Man Homecoming*
2. Write a method that returns the unigram count
3. Write a method that returns the unigram probability
4. Write a method that returns the bigram count
5. Write a method that returns the bigram probability
6. Write a method that returns the sentence probability based on bigrams

*Hints:*

- The next cell gives you some inspiration on how to implement the counting of bigrams
- Everything should be precomputed in the constructor (`__init__`) and the other functions should not recount anything. If implemented efficiently all the computation will be done in a

few seconds (less than 10)!

- This class should be **self-contained** and not depend on any code from previous cells!
- The `window` function is a memory friendly iterator over a list that gives you all n-grams from the list

[35]:
```
'''
Example (you do not need to edit this cell):

Suppose you have a very small corpus consisting of only the
four unique words 'I', 'have', 'a', 'dog' and
the sentence start and end markers '<s>' and '</s>'

The corpus has the three sentences
- <s> I have a dog </s>
- <s> a dog I have </s>
- <s> a dog </s>
'''
import numpy as np

# First we define the index for each word (the order does not matter)
index = {
    'I': 0,
    'have': 1,
    'a': 2,
    'dog': 3,
    '<s>': 4,
    '</s>': 5
}

# These are our bigrams from the sentences
bigrams = [('<s>', 'I'), ('I', 'have'), ('have', 'a'), ('a', 'dog'), ('dog', '</
 ↪s>'),
           ('</s>', '<s>'), ('<s>', 'a'), ('a', 'dog'), ('dog', 'I'), ('I',␣
 ↪'have'), ('have', '</s>'),
           ('</s>', '<s>'), ('<s>', 'a'), ('a', 'dog'), ('dog', '</s>')]

# Next we create a matrix for the bigram counts,
# each entry is a 16 Bit unsigned integer (dtype=np.uint16)
counts = np.zeros((len(index), len(index)), dtype=np.uint16)

# Fill it with the counts
for bigram in bigrams:
    index_first_word = index[bigram[0]]
    index_second_word = index[bigram[1]]
    counts[index_first_word, index_second_word] += 1

# Print out count matrix
```

```
print(counts)

# Check the count for the bigram ('I', 'have'):
print('The bigram ("I", "have") exists {} times.'.format(
    counts[index['I'], index['have']]
))
```

```
[[0 2 0 0 0 0]
 [0 0 1 0 0 1]
 [0 0 0 3 0 0]
 [1 0 0 0 0 2]
 [1 0 2 0 0 0]
 [0 0 0 0 2 0]]
The bigram ("I", "have") exists 2 times.
```

[3]:
```
import numpy as np
from typing import List
from collections import Counter
from itertools import islice
from nltk.corpus import gutenberg

class BigramModel:

    def __init__(self, sentences: List[List[str]]):
        '''
        Takes in a list of sentences, where each sentence is a
        list of words.

        Arguments:
            sentences -- List of lists of words (e.g. [['I', 'have', 'a',␣
 ↪'dog'],
                                                       ['a', 'dog', 'I',␣
 ↪'have']])
        '''
        # YOUR CODE HERE

        #Adding sentnce start '<s>' and ending '</s>'
        for sent in sentences:
            sent.insert(0, '<s>')
            sent.append('</s>')

        # extracting words out of sentences
        self.words = [word for sentence in sentences for word in sentence]

        self.unigrams = Counter(self.words)
        self.vocabulary = self.unigrams.keys()
```

```
        self.index = {word: index for index, word in enumerate(self.vocabulary)}

        self.bigrams = []
        for pair in self.window(self.words):
            self.bigrams.append(pair)

        self.counts = np.zeros((len(self.index), len(self.index)), dtype=np.
 ↪uint16)

        for bigram in self.bigrams:
            index_first_word = self.index[bigram[0]]
            index_second_word = self.index[bigram[1]]
            self.counts[index_first_word, index_second_word] += 1
#         raise NotImplementedError()

    def window(self, seq, n=2):
        '''
        Returns a sliding window (of width n) over data from the iterable

        Arguments:
            seq      -- the iterable (e.g. list, set, etc) to run the window␣
 ↪over
            n        -- the size of the window
        Returns:
            iterator -- an iterator over the sliding windows

        Usage:
            my_list = [1, 2, 3, 4]
            for slice in self.window(my_list):
                print(slice)

            # Output: (1, 2)
                      (2, 3)
                      (3, 4)
        '''
        "Returns a sliding window (of width n) over data from the iterable"
        "   s -> (s0,s1,...s[n-1]), (s1,s2,...,sn), ...                   "
        it = iter(seq)
        result = tuple(islice(it, n))
        if len(result) == n:
            yield result
        for elem in it:
            result = result[1:] + (elem,)
            yield result

    def unigram_count(self, word: str) -> int:
        '''
```

```
        Returns the unigram count for the word.
        If the word does not exist in our corpus, return 0.

        Arguments:
            word  -- word we want to know the count of
        Returns:
            count -- how often the word appears in the corpus
        '''
        # YOUR CODE HERE
        if word in self.vocabulary:
            return self.unigrams[word]
        else:
            return 0
#         raise NotImplementedError()

    def unigram_probability(self, word:str) -> float:
        '''
        Returns the unigram probability for the word.
        If the word does not exist in our corpus, return 0.

        Arguments:
            word        -- word we want to know the probability of
        Returns:
            probability -- how likely it is to choose the word at random
        '''
        # YOUR CODE HERE
        if word in self.vocabulary:
            return self.unigrams[word]/np.sum(list(self.unigrams.values()))
        else:
            return 0
#         raise NotImplementedError()

    def bigram_count(self, word1:str, word2:str) -> int:
        '''
        Returns the bigram count for the word1 followed by word2.
        If either of the words does not exist in our corpus, return 0.

        Arguments:
            word1  -- first word of the bigram
            word2  -- second word of the bigram
        Returns:
            count  -- how often the bigram appears in the corpus
        '''
        # YOUR CODE HERE
        if word1 in self.vocabulary and word2 in self.vocabulary:
            return self.counts[self.index[word1], self.index[word2]]
        else:
```

```
            return 0

#         raise NotImplementedError()

    def bigram_probability(self, word1:str, word2:str) -> float:
        '''
        Returns the bigram probability for the word1 followed by word2.
        This is the conditional probability P(word2 | word1).
        If either of the words does not exist in our corpus, return 0.

        Arguments:
            word1       -- first word of the bigram
            word2       -- second word of the bigram
        Returns:
            probability -- how likely it is to choose the word at random
        '''
        # YOUR CODE HERE
        if word1 in self.vocabulary and word2 in self.vocabulary:
            return self.counts[self.index[word1], self.index[word2]] / self.
 ↪unigrams[word1]
        else:
            return 0
#         raise NotImplementedError()

    def sentence_probability(self, sentence:List[str]) -> float:
        '''
        Return the probability for the given sentence based on our
        bigram probabilities

        Arguments:
            sentence    -- list of tokens from the sentence
                           (e.g. ['<s>', 'I', 'have', 'a', 'dog', '</s>'])
        Returns:
            probability -- probability of the sentence
        '''
        # YOUR CODE HERE
        for word in sentence:
            if word in self.vocabulary:
                continue
            else:
                return 0
        cond_prob = []
        for pair in self.window(sentence):
            cond_prob.append(self.bigram_probability(str(pair[0]),str(pair[1])))
        return np.prod(cond_prob)
#         raise NotImplementedError()
```

```
sents, words = load_data("/srv/shares/NLP/datasets/marvel/spider_man_homecoming.
 ↪pkl")
model = BigramModel(sents)

# Some prints and tests

print('The unigram "Peter" appears {} times in the book!'.format(
    model.unigram_count('Peter')
)) ## Should print 1254

print('The probability for the unigram "Happy" is {:.4f}.'.format(
    model.unigram_probability('Happy')
)) ## Should print 0.0026

print('The bigram "I am" appears {} times in the book!'.format(
    model.bigram_count('I', 'am')
)) ## Should print 3

print('The probability for the bigram "I have" is {:.4f}.'.format(
    model.bigram_probability('I', 'have')
)) ## Should print 0.0233

print('The sentence probability for the sentence "Alien artifacts lie among the␣
 ↪rubble." is {:.4e}.'.format(
    model.sentence_probability(['<s>', 'Alien', 'artifacts', 'lie', 'among',␣
 ↪'the', 'rubble', '.', '</s>'])
)) ## Should print 7.2583e-08
```

```
The unigram "Peter" appears 1254 times in the book!
The probability for the unigram "Happy" is 0.0026.
The bigram "I am" appears 3 times in the book!
The probability for the bigram "I have" is 0.0233.
The sentence probability for the sentence "Alien artifacts lie among the
rubble." is 7.2583e-08.
```

[ ]:

### 1.4 2.2) Using the model [10 Points]

With our model we can now answer some questions.

1. How often does a certain word appear in the movie?
   - Give the number of times the word 'Avengers' appears in the book - Store this in the variable `count_Avengers`.
   - Give the number of times the word 'She' appears in the book - Store this in the variable `count_She`.
2. How many sentences start or end with a certain word or token?

- Give the probability that a sentence starts with the word 'I' - Store this in the variable `p_sentence_begins_with_I`
- Give the probability that a sentence ends with '!' in contrast to sentences ending in other words - Store this in the variable `p_sentence_ends_in_exlamation`

[5]:
```
sentences, _ = load_data("/srv/shares/NLP/datasets/marvel/spider_man_homecoming.
↪pkl")
model = BigramModel(sentences)

count_Avengers = 0
count_She = 0
p_sentence_begins_with_I = 0
p_sentence_ends_in_exlamation = 0

# YOUR CODE HERE
count_Avengers = model.unigram_count('Avengers')
count_She = model.unigram_count('She')
p_sentence_begins_with_I = model.bigram_probability('<s>','I')
p_sentence_ends_in_exlamation = model.bigram_probability('!','</s>')
# raise NotImplementedError()

print('The word "Avengers" appears {} time(s) in the movie.'.format(
    count_Avengers
))
print('The word "She" appears {} time(s) in the movie.'.format(
    count_She
))
print('The probability that a sentence starts with "I" is {:.4f}'.format(
    p_sentence_begins_with_I
))
print('The probability that a sentence ends in "!" is {:.4f}'.format(
    p_sentence_ends_in_exlamation
))
```

```
The word "Avengers" appears 22 time(s) in the movie.
The word "She" appears 17 time(s) in the movie.
The probability that a sentence starts with "I" is 0.0415
The probability that a sentence ends in "!" is 0.9827
```

[ ]:
```
# This is a test cell, please ignore it!
```

### 1.4.1 Generating Random Sentences

You are given the following function that given a model can generate random sentences.

You might need to change some lines if your implementation significantly differs from mine, but the idea is to:

- Have a reverse index where an id is mapped to a token

- Have an index where a token is mapped to an id
- Have a bigram_counts matrix

Whenever you execute the function it will generate a random sentence. You can also try this with the other movies.

**This is not graded**

[6]:
```
import random as rd

def generate_random_sentence(model):
    start = '<s>'
    end = '</s>'


    reverse_index = {value: key for key, value in model.index.items()}

    sentence = [start]
    token = sentence[-1]
    while token != end:

        index = model.index[token]
        row = model.bigram_counts[index, :]
        token = rd.choices(range(len(row)), weights=row)[0]
        token = reverse_index[token]
        sentence.append(token)

    return ' '.join(sentence)

sentences, _ = load_data("/srv/shares/NLP/datasets/marvel/guardians_2.pkl")
model = BigramModel(sentences)
generate_random_sentence(model)
```

```
---------------------------------------------------------------------------
AttributeError                            Traceback (most recent call last)
Cell In[6], line 24
     22 sentences, _ = load_data("/srv/shares/NLP/datasets/marvel/guardians_2.
 ↪pkl")
     23 model = BigramModel(sentences)
---> 24 generate_random_sentence(model)

Cell In[6], line 15, in generate_random_sentence(model)
     12 while token != end:
     14     index = model.index[token]
---> 15     row = model.bigram_counts[index, :]
     16     token = rd.choices(range(len(row)), weights=row)[0]
     17     token = reverse_index[token]
```

```
AttributeError: 'BigramModel' object has no attribute 'bigram_counts'
```

[ ]: