CS 6320 Project Report

Question Answering System

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Problem Description

The aim is to build a question-answering system that uses NLP features and techniques which can extract information from the provided SQuAD dataset and return the sentences containing the answer for the input question.

Proposed Solution

We use NLP techniques to extract the sematic & syntactic information from these articles and use them to find closest answer to the user's question. We'll extract NLP features like tokenized words, POS tags, lemmas, synonyms, hypernyms, meronyms, holonyms, dependency tree, name-entities etc. for every sentence, and use SOLR tool to index these extracted features and sentence. We'll extract the same features from the question and form a SOLR search query. The questions can be subcategorized into Who, What and When questions. Based on the subcategory of the question and the query string generated from the question, we return ten sentences with their features and their relevant score. Based on their score, we first smooth it and then calculate how many features do they match with the question. Finally, we pick the sentence with the highest score.

Implementation Details

Programming Tools

- Python 3.8.5
- Spacy library (name entity recognition, dependency tree)
- Apache Solr 8.10.1

  Run Solr and create the collection named "gettingstarted"
- NLTK library (wordnet, stopwords, PorterStemmer, Lemmatizer, POS tags)
- Scikit-Learn (TfidfVectorizer, cosine_similarity)

Architectural Diagram

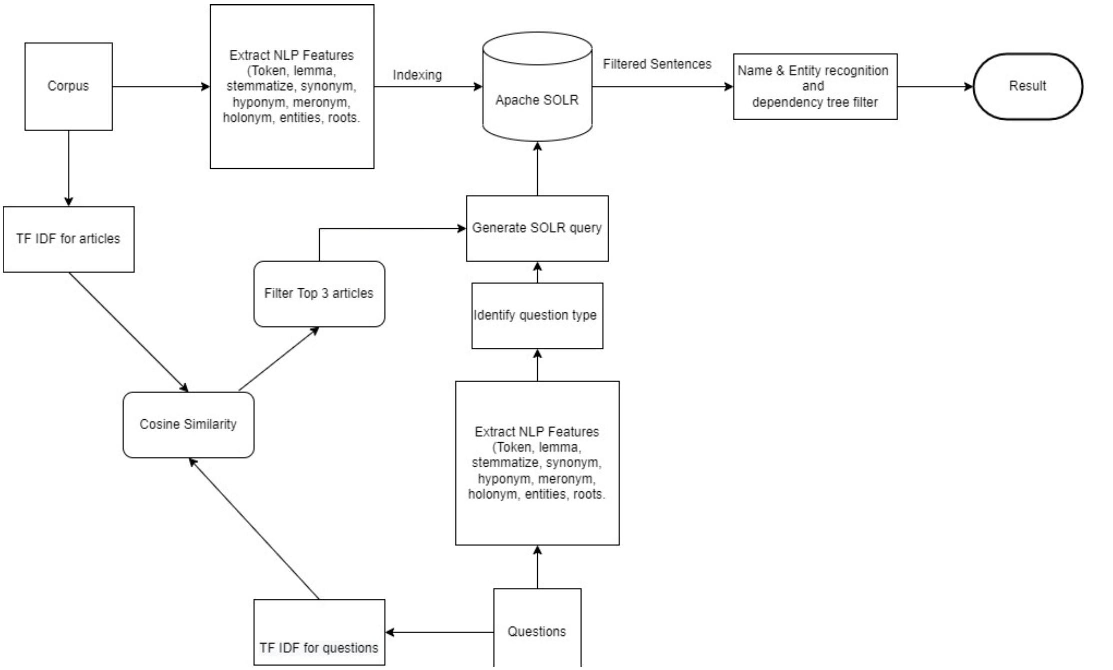

Corpus
Extract NLP Features (Token, lemma, stemmatize, synonym, hyponym, meronym, holonym, entities, roots.
Indexing
Apache SOLR
Filtered Sentences
Name & Entity recognition and dependency tree filter
Result
TF IDF for articles
Generate SOLR query
Filter Top 3 articles
Identify question type
Cosine Similarity
Extract NLP Features (Token, lemma, stemmatize, synonym, hyponym, meronym, holonym, entities, roots.
TF IDF for questions
Questions

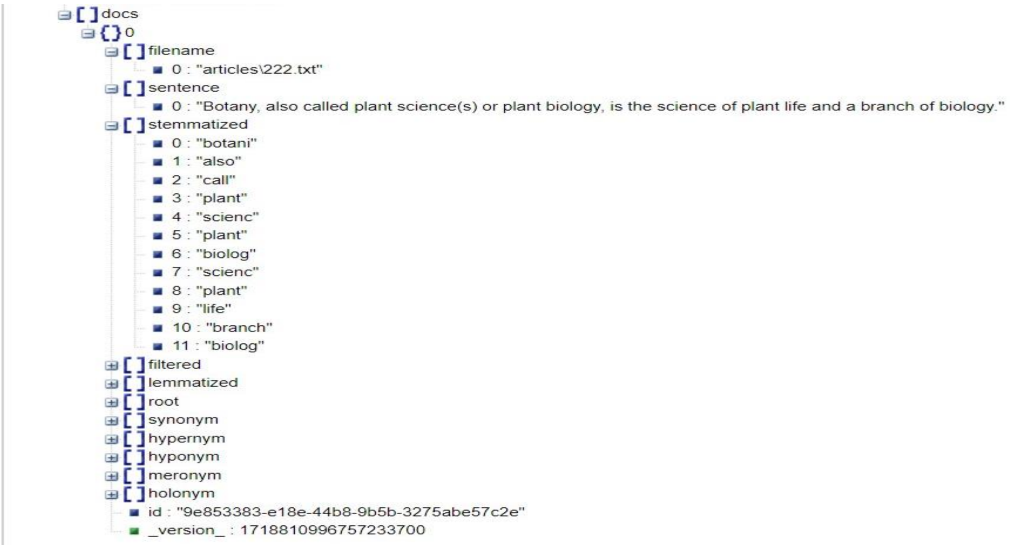
Figure 1 Architectural Diagram

Step 1:

- Read the file and do sentence tokenization.
- Extract the NLP features from each sentence including, word tokenization without stop words, lemmatization, stemming, synonyms, hypernyms, holonyms, meronyms, named entity, dependency parsed tree.

Step 2:

- Connect to Solr collection which named “gettingstarted”
- Send the sentence with the filename and it’s NLP features to Solr for indexing.
- For indexing, we send a sentence-based dictionary in to Solr.



```
[ ]docs
  { }0
    [ ]filename
        0 : "articles\222.txt"
    [ ]sentence
        0 : "Botany, also called plant science(s) or plant biology, is the science of plant life and a branch of biology."
    [ ]stemmatized
        0 : "botani"
        1 : "also"
        2 : "call"
        3 : "plant"
        4 : "scienc"
        5 : "plant"
        6 : "biolog"
        7 : "scienc"
        8 : "plant"
        9 : "life"
        10 : "branch"
        11 : "biolog"
    [ ]filtered
    [ ]lemmatized
    [ ]root
    [ ]synonym
    [ ]hypernym
    [ ]hyponym
    [ ]meronym
    [ ]holonym
      id : "9e853383-e18e-44b8-9b5b-3275abe57c2e"
      _version_ : 1718810996757233700
```

Figure 2 Index structure in Solr

In above figure 2, because the data is too long, I use JSON viewer to format it. You can easily see the structure from this figure.

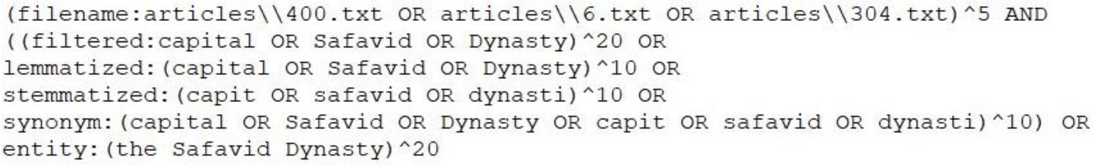
Step 3:

- Read the questions and extract NLP features from questions, including tokenization, lemmatization, stemming, wordnet, name entity recognition, dependency tree.
- Using TF-IDF to get top-3 relevant articles with documents and given question.

Step 4:

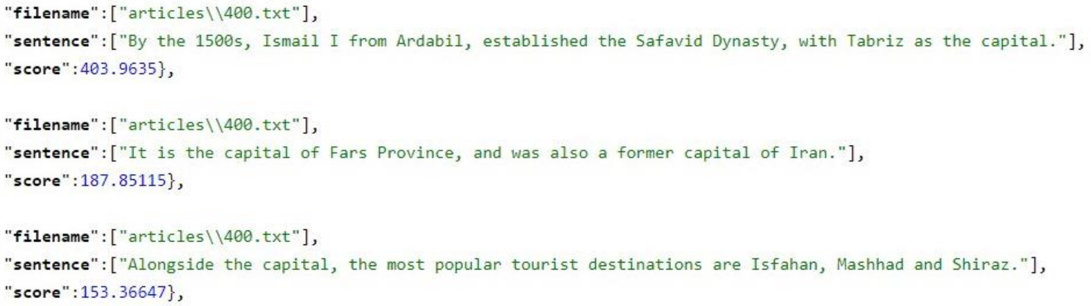
- Identify “what” or “when” or “who” question.
- Form the query based on features for each type of question.
- We use tokens, 3 relevant articles, lemma, stemma, entity text, entity labels, synonyms to form the query.
- For entity labels, we use “DATE” or “TIME” for “when” question, “ORG” or “PERSON” for “who” question.

Figure 3 is the example of forming the query. The question is “What was the capital of the Safavid Dynasty?”



```
(filename:articles\\400.txt OR articles\\6.txt OR articles\\304.txt)^5 AND
((filtered:capital OR Safavid OR Dynasty)^20 OR
lemmatized:(capital OR Safavid OR Dynasty)^10 OR
stemmatized:(capit OR safavid OR dynasti)^10 OR
synonym:(capital OR Safavid OR Dynasty OR capit OR safavid OR dynasti)^10) OR
entity:(the Safavid Dynasty)^20
```

Figure 3 Query Example



```
"filename":["articles\\400.txt"],
"sentence":["By the 1500s, Ismail I from Ardabil, established the Safavid Dynasty, with Tabriz as the capital."],
"score":403.9635},

"filename":["articles\\400.txt"],
"sentence":["It is the capital of Fars Province, and was also a former capital of Iran."],
"score":187.85115},

"filename":["articles\\400.txt"],
"sentence":["Alongside the capital, the most popular tourist destinations are Isfahan, Mashhad and Shiraz."],
"score":153.36647},
```

Figure 4 Search Result

Step 5:

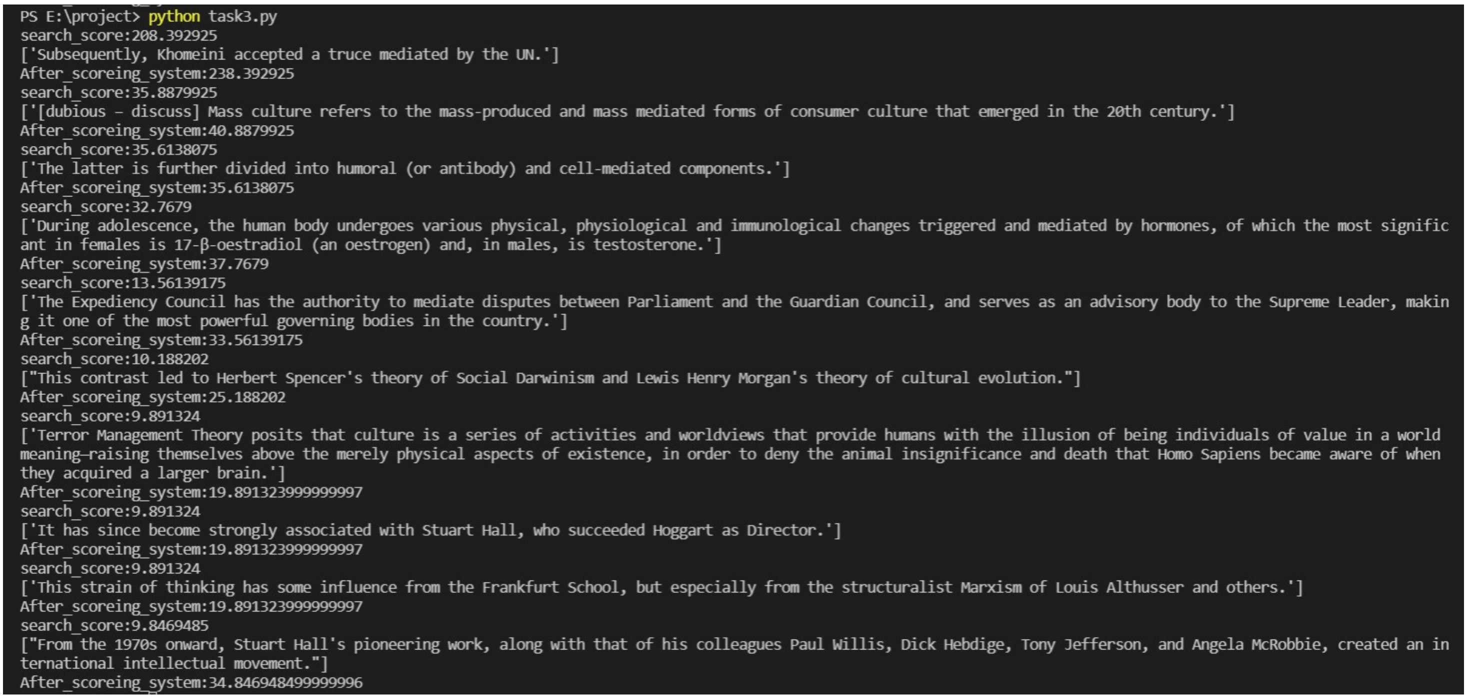
- Get scores from the query result and form a scoring system based on their sentence features.
- In this scoring system, we use dependency tree features of question to identify the direct object and subject, whether these texts exist in the sentences or not. If they exist, we add score to their original score.
- Then, we use name entity recognition to match sentence with question. We first

identify whether there is entity label for each type of question, such as “DATE” or “Time” for When, “ORG” or “PERSON” for Who. If the sentence has that kind of label, we will first give them reward then match their entity text, see whether it appears in the question, if yes, then reward the sentence again. On the other hand, if there is no such kind of label, we then see their entity text, whether it appears in the question. If yes, then we give that sentence reward.

- Next, we look into token, if it appears in the question’s synonym, then we give the sentence reward, else if it appears in the question’s hypernym, we give the sentence reward, else if it appears in the question’s hyponym, we give the sentence reward.

	Entity_text	Token	Entity_label	Lemma & Stem	Synonym	Hypernym	Hyponym
reward	5	10	5	5	5	1	1

- After calculating, we get the best answer with the top score and store it in the list named “best” as the format [Article_Name, Question, Answer].



```
PS E:\project> python task3.py
search_score:208.392925
['Subsequently, Khomeini accepted a truce mediated by the UN.']
After_scoreing_system:238.392925
search_score:35.8879925
['[dubious – discuss] Mass culture refers to the mass-produced and mass mediated forms of consumer culture that emerged in the 20th century.']
After_scoreing_system:40.8879925
search_score:35.6138075
['The latter is further divided into humoral (or antibody) and cell-mediated components.']
After_scoreing_system:35.6138075
search_score:32.7679
['During adolescence, the human body undergoes various physical, physiological and immunological changes triggered and mediated by hormones, of which the most signific
ant in females is 17-β-oestradiol (an oestrogen) and, in males, is testosterone.']
After_scoreing_system:37.7679
search_score:13.56139175
['The Expediency Council has the authority to mediate disputes between Parliament and the Guardian Council, and serves as an advisory body to the Supreme Leader, makin
g it one of the most powerful governing bodies in the country.']
After_scoreing_system:33.56139175
search_score:10.188202
["This contrast led to Herbert Spencer's theory of Social Darwinism and Lewis Henry Morgan's theory of cultural evolution."]
After_scoreing_system:25.188202
search_score:9.891324
['Terror Management Theory posits that culture is a series of activities and worldviews that provide humans with the illusion of being individuals of value in a world
meaning—raising themselves above the merely physical aspects of existence, in order to deny the animal insignificance and death that Homo Sapiens became aware of when
they acquired a larger brain.']
After_scoreing_system:19.891323999999997
search_score:9.891324
['It has since become strongly associated with Stuart Hall, who succeeded Hoggart as Director.']
After_scoreing_system:19.891323999999997
search_score:9.891324
['This strain of thinking has some influence from the Frankfurt School, but especially from the structuralist Marxism of Louis Althusser and others.']
After_scoreing_system:19.891323999999997
search_score:9.8469485
["From the 1970s onward, Stuart Hall's pioneering work, along with that of his colleagues Paul Willis, Dick Hebdige, Tony Jefferson, and Angela McRobbie, created an in
ternational intellectual movement."]
After_scoreing_system:34.846948499999996
```

Figure 5 Score System example

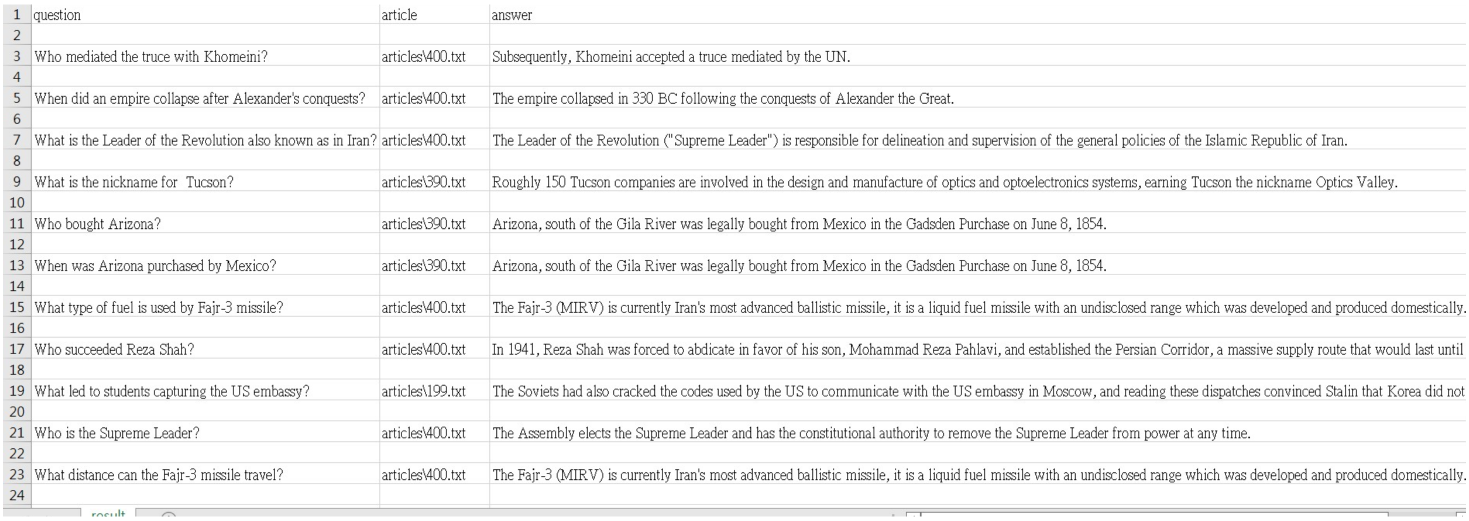
Figure 5 is the example of score system, the search question is “Who mediated the truce with Khomeini?”. You can see that the system selects the best sentence with the highest score.

Step 6:

- Getting the best list and output as an csv file.

Result & Error Analysis

Figure 6 shows our result of Sample Question Answering Data.
The accuracy of this data runs quite well.



1	question	article	answer
2			
3	Who mediated the truce with Khomeini?	articles\400.txt	Subsequently, Khomeini accepted a truce mediated by the UN.
4			
5	When did an empire collapse after Alexander's conquests?	articles\400.txt	The empire collapsed in 330 BC following the conquests of Alexander the Great.
6			
7	What is the Leader of the Revolution also known as in Iran?	articles\400.txt	The Leader of the Revolution ("Supreme Leader") is responsible for delineation and supervision of the general policies of the Islamic Republic of Iran.
8			
9	What is the nickname for Tucson?	articles\390.txt	Roughly 150 Tucson companies are involved in the design and manufacture of optics and optoelectronics systems, earning Tucson the nickname Optics Valley.
10			
11	Who bought Arizona?	articles\390.txt	Arizona, south of the Gila River was legally bought from Mexico in the Gadsden Purchase on June 8, 1854.
12			
13	When was Arizona purchased by Mexico?	articles\390.txt	Arizona, south of the Gila River was legally bought from Mexico in the Gadsden Purchase on June 8, 1854.
14			
15	What type of fuel is used by Fajr-3 missile?	articles\400.txt	The Fajr-3 (MIRV) is currently Iran's most advanced ballistic missile, it is a liquid fuel missile with an undisclosed range which was developed and produced domestically.
16			
17	Who succeeded Reza Shah?	articles\400.txt	In 1941, Reza Shah was forced to abdicate in favor of his son, Mohammad Reza Pahlavi, and established the Persian Corridor, a massive supply route that would last until
18			
19	What led to students capturing the US embassy?	articles\199.txt	The Soviets had also cracked the codes used by the US to communicate with the US embassy in Moscow, and reading these dispatches convinced Stalin that Korea did not
20			
21	Who is the Supreme Leader?	articles\400.txt	The Assembly elects the Supreme Leader and has the constitutional authority to remove the Supreme Leader from power at any time.
22			
23	What distance can the Fajr-3 missile travel?	articles\400.txt	The Fajr-3 (MIRV) is currently Iran's most advanced ballistic missile, it is a liquid fuel missile with an undisclosed range which was developed and produced domestically.
24			

Figure 6 Result of Sample Question Answering Data

We have noticed that it might select the wrong answer when sentences having same entity, such as the question "What is FARMS" from 281.txt, our answer for that question is "Thus was born the FARMS Critical Text Project which published the first volume of the 3-volume Book of Mormon Critical Text in 1984." The answer is "By 1979, with the establishment of the Foundation for Ancient Research and Mormon Studies (FARMS) as a California non-profit research institution, an effort led by Robert F. Smith began to take full account of Larson's work and to publish a Critical Text of the Book of Mormon." They both have FARMS, but in our search result, our answer has higher score than the correct answer.

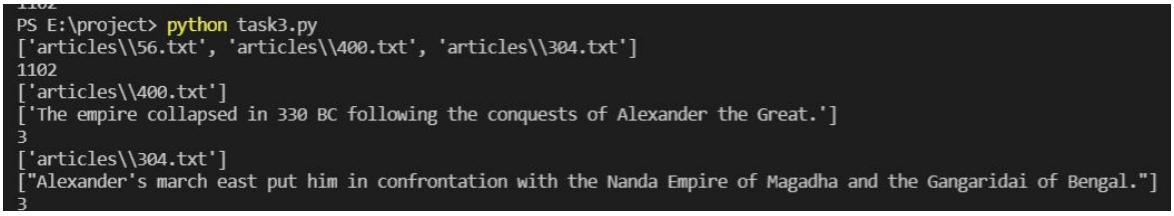
In figure 6, you can see that the system selects the wrong answer in row 21, because it also has the Supreme Leader.

Problems Encountered

1. **Not finding relevant articles in Solr search query.**
   When we first use TF-IDF to find the top 3 relevant articles, the accuracy of finding the correct answer was lower than not using TF-IDF. We investigated the search result, and we discovered that the result contains articles which is not in the set of relevant articles. It turned out that it is because of q.op which is the query

operator. In default, q.op is OR and that’s why we had sentences out of the relevant articles. We set q.op to AND via pysolr search.

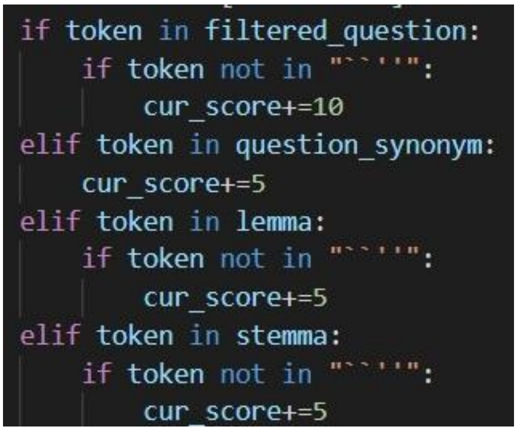
2. **Search result is hard to discriminate.**
   After searching, we tried to get the score of each sentence by only counting their features, however, this is hard to discriminate their score. Thus, we tried to use the relevance score from Solr given the weight that we set in query. However, some sentences score is too large, and it is not enough to say it is the best sentence via solr search. In this case, we smoothed the score. We divided the score by 4 and using this score to be the base score then we calculate the features. In the below figure, you can see that we have 2 sentences with the same score, but it only chooses the first sentence.



```
PS E:\project> python task3.py
['articles\\56.txt', 'articles\\400.txt', 'articles\\304.txt']
1102
['articles\\400.txt']
['The empire collapsed in 330 BC following the conquests of Alexander the Great.']
3
['articles\\304.txt']
["Alexander's march east put him in confrontation with the Nanda Empire of Magadha and the Gangaridai of Bengal."]
3
```

Figure 7 Search result hard to discriminate

3. **Some punctuation and useless words still exist in the sentence.**
   Although we extracted the stop words while tokenizing, there still some useless words or punctuation exists. For example, ``”, they still exist after tokenizing. Therefore, we had to make sure it will not be counted when calculating the features.



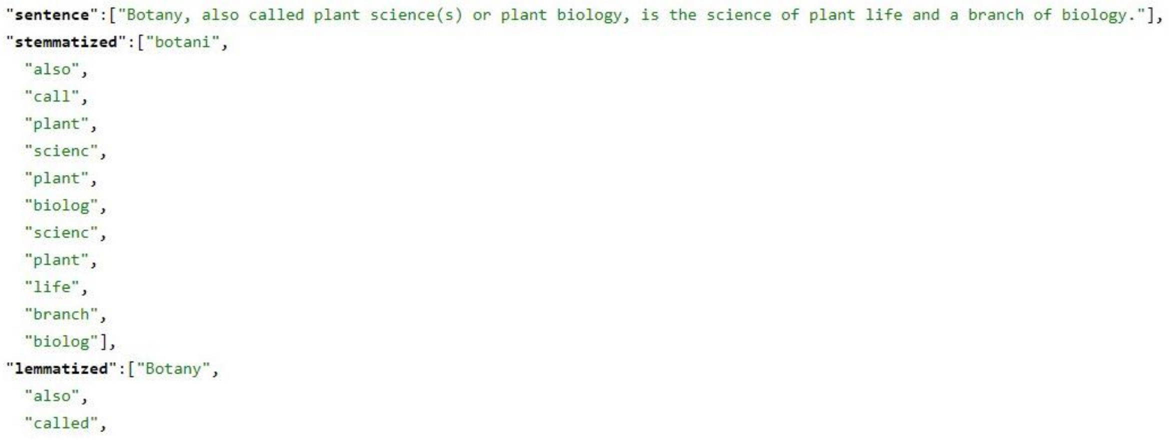
```
if token in filtered_question:
    if token not in "``''":
        cur_score+=10
elif token in question_synonym:
    cur_score+=5
elif token in lemma:
    if token not in "``''":
        cur_score+=5
elif token in stemma:
    if token not in "``''":
        cur_score+=5
```

Figure 8 Check if the token is not in ``”

4. **TF-IDF is a case sensitive model.**
   Previously, we used lowercase to transform the model, however, we ignored the fact that articles may use the abbreviation such as FARMS, which is stands for Foundation for Ancient Research and Mormon Studies. In this case, if we ignore the case, TF-IDF will match the articles which contain farms, which means an

area of land that is used for growing crops and raising animals. Therefore, we then use the original cases to transform and fit the model.

5. **Some word stays the same after lemmatizing.**
   Lemmatization usually refers to doing things properly with the use of a vocabulary and morphological analysis of words, normally aiming to remove inflectional endings only and to return the base or dictionary form of a word, which is known as the lemma. However, it is hard to be searched in synonym with only lemmatization. Also, the past tense may not include in question. Therefore, we introduce Porter Stemmer in NLTK.
   For example, called in lemma is still “called”, but in stemming is “call”

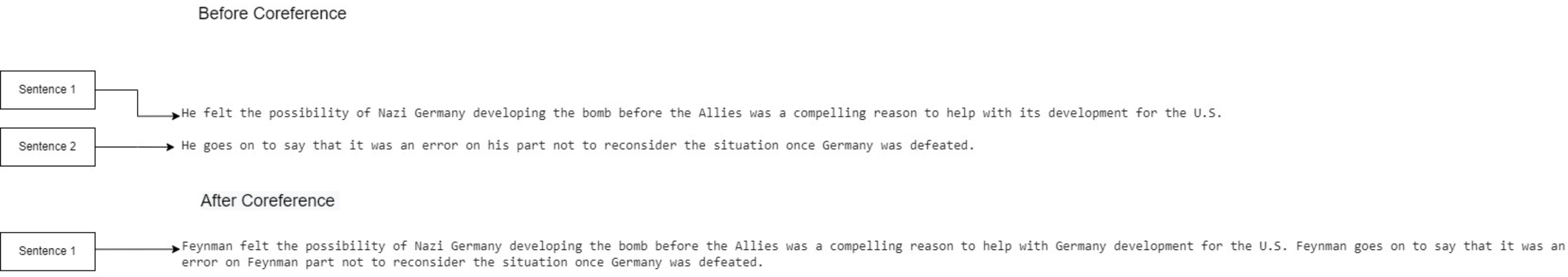


```
"sentence":["Botany, also called plant science(s) or plant biology, is the science of plant life and a branch of biology."],
"stemmatized":["botani",
  "also",
  "call",
  "plant",
  "scienc",
  "plant",
  "biolog",
  "scienc",
  "plant",
  "life",
  "branch",
  "biolog"],
"lemmatized":["Botany",
  "also",
  "called",
```

Figure 9 example of the lemmatization and stemming difference

Pending Issues

1. **spaCy coreference tool seems weird after sentence tokenization.**
   We previously wanted to use spaCy coreference in our project. Although we finish doing the coreference part. It became weird when we did sentence tokenization. We tried using different sentence tokenizing tool. It is still weird. Therefore, we gave up using coreference as a tool. If we have enough time, we can implement sentence tokenization on our own and maybe this will work for coreference.



He felt the possibility of Nazi Germany developing the bomb before the Allies was a compelling reason to help with its development for the U.S.

He goes on to say that it was an error on his part not to reconsider the situation once Germany was defeated.

Feynman felt the possibility of Nazi Germany developing the bomb before the Allies was a compelling reason to help with Germany development for the U.S. Feynman goes on to say that it was an error on Feynman part not to reconsider the situation once Germany was defeated.

Figure 10 Coreference Issues

2. **The accuracy still needs to be improved even using dependency tree.**

The accuracy still needs to be improved.

Potential Improvements

1. **Using more dependency features to get the correct answer.**
   In our code, we only use dobj and nsubj to check whether sentences' structure match to the question. We can use more dependency tree's feature to get the correct answer.
2. **Using Coreference as a feature to extract the correct sentence.**
   Just like we mentioned previously, because we failed at using it, if we have more time, we want to implement Coreference in our code and make use of it.
3. **Using Elastic Search instead of Apache Solr.**
   It seems that Elastic Search contain more features and tools than Solr. It will be more convenient to use Elastic Search than Apache Solr.