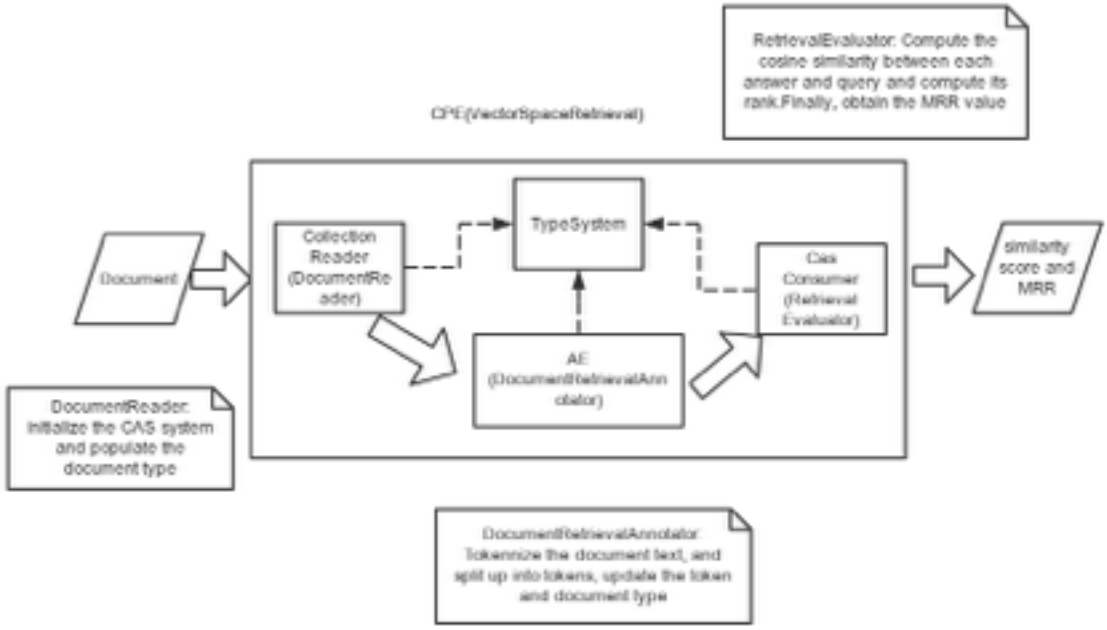
Hw3 Engineering and Error Analysis with UIMA

1 Task 1

The System Framework(showed in the figure below) is consist of four main components and they are implemented by the following java class.



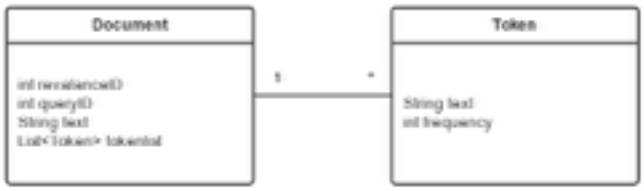
CPE: VectorSpaceRetrieval.java
CollectionReader: DocumentReader.java.
It reads file and splits each sentence into some parts in order to fill up the properties of document and update CAS.
Annotator: DocumentVectorAnnotator.java.
Here, I use HashMap to store the tokens and their frequency. By reading each document text, I compute the times that each token shows up. Then, I construct a vector of tokens and update the tokenList in CAS.
CasConsumer: RetrievalEvaluator.java.

This is the heart of the whole system, where I calculate cosine similarity between the query and its answer, find out the rank of the given answer sentence with relevance 1, and compute the MRR with all of the ranks.
Here are two main functions that is the processCas(), and collectionProcessComplete(). Because the pipeline processes one CAS at a time, I store data in memory as some private variable mem-

bers, like query id number list, text relevant values list, rankList storing ranks of each answer with relevance 1.

Here is a flow chart of logical design of processCas() method.

In collectionProcessComplete(), I calculate the final MRR of all the ranks in the rankList.
TypeSystem: Token.java, Document.java. Here is a class diagram for the type system.



```
cosine=0.2791   rank=2  qid=1   rel=1   In A.D. 79, long-dormant Mount Vesuvius erupted, burying in volc
cosine=0.2858   rank=2  qid=2   rel=1   When Michael Jordan--one of the greatest basketball player of al
cosine=0.2357   rank=3  qid=3   rel=1   Alaska was purchased from Russia in year 1867.
cosine=0.2315   rank=2  qid=4   rel=1   On March 2, 1962, Wilt Chamberlain scored a record 100 points ir
cosine=0.0000   rank=3  qid=5   rel=1   People of China have mixed feelings about  River, which they oft
cosine=0.5547   rank=2  qid=6   rel=1   Roger Bannister was the first to break the four-minute mile barr
cosine=0.0891   rank=3  qid=7   rel=1   And that's not even to mention the breathtaking beauty of Alaska
cosine=0.1833   rank=2  qid=8   rel=1   Fighting for Holyfield's WBA heavyweight title on June 28, 1997,
cosine=0.5804   rank=2  qid=9   rel=1   Luna 2 was the first spacecraft to reach the surface of the Moor
cosine=0.5000   rank=1  qid=10  rel=1   Menchu won the Nobel peace prize in 1992.
cosine=0.1768   rank=4  qid=11  rel=1   Devils Tower can be found in Crook County
cosine=0.3162   rank=3  qid=12  rel=1   Named the "Mendocino Tree," the 600- to 800-year-old redwood   s
cosine=0.1195   rank=3  qid=13  rel=1   Oregon's Crater Lake tops it at 1,932 feet at its greatest depth
cosine=0.4216   rank=2  qid=14  rel=1   Lionel Richiewas was lead singer and songwriter for Commodores.
cosine=0.0788   rank=3  qid=15  rel=1   A new look at NASA satellite data revealed that Earth set a new
cosine=0.2828   rank=3  qid=16  rel=1   Bob Marley died in 1981 from cancer at age 36.
cosine=0.1508   rank=3  qid=17  rel=1   Corn futures found support from forecasts for above-normal   tem
cosine=0.2265   rank=2  qid=18  rel=1   From a single hamburger stand in San Bernardino, Calif., in 1948
cosine=0.1268   rank=3  qid=19  rel=1   On May 6, 1937, the hydrogen-filled German dirigible Hindenburg
cosine=0.3078   rank=2  qid=20  rel=1   They call it the Keystone State, and in this unpredictable elect
MRR=0.4374999999999999
```

Above is the report results: MRR=0.43749999

2 Task 2 Error Analysis

The following table is a summary of error types.

ID	Description	Error Type	Frequency
0	misspelling, like "Pompei", "Aaska"	Misspelling	4
1	Too many tokens, describing in details, like the gold answer in the first query	Long Length	9
2	punctuation missed or inserted, like A and A's are considered as different token	Punctuation Mismatched	5
3	the different tense of one verb is considered differently	Tense Variants(Morphological Variants)	4
4	explain the same meaning with another description, like spaceship and spacecraft	Vocabulary Mismatch (Paraphrase Mismatch)	10
5	Lowercase and uppercase mismatched	Letter Case Error	4
6	function words like "a", "and", "the" help higher other less related answers' rank, thus lowering gold document's rank	Stop Words Interference	5
7	singular and plural form	Noun Form Variants(Morphological Variants)	3
8	other irrelevant answers overlap more tokens in the query document, but fail to answer what the query ask. For example, the query ask for "when", but the irrelevant answer just repeats what the query describes.	Irrelevant Answers Disturbance	5

3. Task 2 Improvements Based on Error Analysis

Based on these types, I camp up with improvements from three aspects.
Here is a table for Improvements.

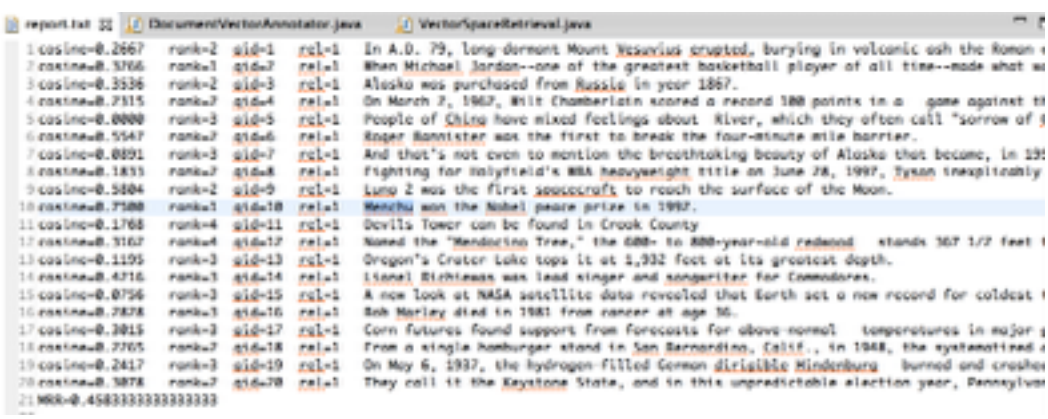
Note: All the improvements could be checked in my github repository. https://github.com/eyrelzy/hw3-zhiyuel2.

	Improvements			
ID	Solution	Improvement document('+' means getting higher rank, while '-' means lower its rank)	# of correct hit(baseline is 1)	MRR(baseline is 0.43)
1	Normalize a token , remove case sensitive(case conversion)	+3	2	0.4583
2	remove 's & s'	+2	3	0.4792
3	remove punctuation	+9	7	0.6125
4	introduce stem, Map a token to another token (solve morphological variants)	+4-2	8	0.6542
5	discard stop words	+1-5	9	0.6500
6	misspelling like more than one white spaces:Trim the text first, and also remove whose length is zero.	0	9	0.6500
7	Split up compound into several words	+1	10	0.675
8	First remove some punctuation, then do stemming method, and choose one of the scoring methods below			
8.0	cosine similarity	+2-1	11	0.7042
8.1	TF-IDF	+2-1	10	0.7125
8.2	BM25	+5-3	12	0.7823

1.Tokenize Improvement:

1) Normalize a token, case conversion:

By doing so, MRR increases by 0.4583, three items' rank increase, and even one successfully selects the most relevant answer.



For exmple:

qid=10 rel=99 Who won the **Nobel Peace Prize** in 1992?

qid=10 rel=1 Menchu won the **Nobel peace prize** in 1992.

After turning all the letters into lowercase, query 10 selected the gold answer.

2) Remove 's and s' :
Increase two ranks, and hit three gold answers. However, this could also introduce some errors because of the part of speech difference for each word, for example, in general and general's have different meanings, and we should distinguish them.

```
1 cosine=0.2667   rank=2  qid=1   rel=1   In A.D. 79, long-dormant Mount Vesuvius erupted, burying in volc
2 cosine=0.3266   rank=1  qid=2   rel=1   When Michael Jordan--one of the greatest basketball player of all
3 cosine=0.3536   rank=2  qid=3   rel=1   Alaska was purchased from Russia in year 1867.
4 cosine=0.2315   rank=2  qid=4   rel=1   On March 2, 1962, Wilt Chamberlain scored a record 100 points in
5 cosine=0.0990   rank=3  qid=5   rel=1   People of China have mixed feelings about  River, which they ofte
6 cosine=0.5547   rank=2  qid=6   rel=1   Roger Bannister was the first to break the four-minute mile barri
7 cosine=0.0845   rank=4  qid=7   rel=1   And that's not even to mention the breathtaking beauty of Alaska
8 cosine=0.1833   rank=2  qid=8   rel=1   Fighting for Holyfield's WBA heavyweight title on June 28, 1997,
9 cosine=0.5804   rank=2  qid=9   rel=1   Luna 2 was the first spacecraft to reach the surface of the Moon.
10 cosine=0.7500  rank=1  qid=10  rel=1   Menchu won the Nobel peace prize in 1992.
11 cosine=0.1768  rank=4  qid=11  rel=1   Devils Tower can be found in Crook County
12 cosine=0.3162  rank=4  qid=12  rel=1   Named the "Mendocino Tree," the 600- to 800-year-old redwood   st
13 cosine=0.1195  rank=3  qid=13  rel=1   Oregon's Crater Lake tops it at 1,932 feet at its greatest depth,
14 cosine=0.4216  rank=3  qid=14  rel=1   Lionel Richiewas was lead singer and songwriter for Commodores.
15 cosine=0.0756  rank=3  qid=15  rel=1   A new look at NASA satellite data revealed that Earth set a new r
16 cosine=0.2828  rank=3  qid=16  rel=1   Bob Marley died in 1981 from cancer at age 36.
17 cosine=0.3015  rank=3  qid=17  rel=1   Corn futures found support from forecasts for above-normal   temp
18 cosine=0.2831  rank=1  qid=18  rel=1   From a single hamburger stand in San Bernardino, Calif., in 1948,
19 cosine=0.2417  rank=3  qid=19  rel=1   On May 6, 1937, the hydrogen-filled German dirigible Hindenburg
20 cosine=0.3078  rank=2  qid=20  rel=1   They call it the Keystone State, and in this unpredictable electi
21 MRR=0.4791666666666667
```

i.e. qid=18 rel=99 Where was the first McDonald's built?
Removing "'s" from helps generate a key word "mcdonald".

3) improve punctuation like "," in token "1823,":
It enhances 8 ranks, also hit 7 gold answers.

```
1 cosine=0.3112   rank=2  qid=1   rel=1   In A.D. 79, long-dormant Mount Vesuvius erupted, burying
2 cosine=0.3266   rank=1  qid=2   rel=1   When Michael Jordan--one of the greatest basketball play
3 cosine=0.3536   rank=2  qid=3   rel=1   Alaska was purchased from Russia in year 1867.
4 cosine=0.3086   rank=1  qid=4   rel=1   On March 2, 1962, Wilt Chamberlain scored a record 100 p
5 cosine=0.3062   rank=2  qid=5   rel=1   People of China have mixed feelings about  River, which
6 cosine=0.5547   rank=2  qid=6   rel=1   Roger Bannister was the first to break the four-minute m
7 cosine=0.1690   rank=3  qid=7   rel=1   And that's not even to mention the breathtaking beauty o
8 cosine=0.2750   rank=2  qid=8   rel=1   Fighting for Holyfield's WBA heavyweight title on June 2
9 cosine=0.6529   rank=1  qid=9   rel=1   Luna 2 was the first spacecraft to reach the surface of
10 cosine=0.8750  rank=1  qid=10  rel=1   Menchu won the Nobel peace prize in 1992.
11 cosine=0.1768  rank=4  qid=11  rel=1   Devils Tower can be found in Crook County
12 cosine=0.3953  rank=3  qid=12  rel=1   Named the "Mendocino Tree," the 600- to 800-year-old red
13 cosine=0.2390  rank=3  qid=13  rel=1   Oregon's Crater Lake tops it at 1,932 feet at its greate
14 cosine=0.5270  rank=1  qid=14  rel=1   Lionel Richiewas was lead singer and songwriter for Comm
15 cosine=0.1512  rank=3  qid=15  rel=1   A new look at NASA satellite data revealed that Earth se
16 cosine=0.2828  rank=3  qid=16  rel=1   Bob Marley died in 1981 from cancer at age 36.
17 cosine=0.3769  rank=2  qid=17  rel=1   Corn futures found support from forecasts for above-norm
18 cosine=0.2831  rank=1  qid=18  rel=1   From a single hamburger stand in San Bernardino, Calif.,
19 cosine=0.2820  rank=3  qid=19  rel=1   On May 6, 1937, the hydrogen-filled German dirigible Hin
20 cosine=0.4184  rank=1  qid=20  rel=1   They call it the Keystone State, and in this unpredictab
21 MRR=0.6125
```

i.e. qid=18 rel=99 Where was the first McDonald's built?
Removing "?" from helps generate a key word "built".

4) misspelling like more than one white spaces:
Trim the text first, and also remove whose length is zero.
i.e. qid=19 rel=1 On May 6, 1937, the hydrogen-filled German dirigible Hindenburg burned and crashed in Lakehurst, N.J., killing 35 of the 97 people on board and a Navy crewman on the ground.
There are more than one spaces between the words in red.

2. Stemming Improvement:
1) Given stemming method:

After using the given stemming method, it improves the MRR value due to correcting some morphological variants errors since it enables a broader range of queries to (correctly) match. i.e. here purchase has morphological variants.
qid=3 rel=99 In which year did a purchase of Alaska happen?
qid=3 rel=1 Alaska was purchased from Russia in year 1867.

After stemming, we have the following sentences.

in which year do a purchase of alaska happen?
alaska be purchase from russium in year 1867.

However, it also lower someone's rank, such as the 18 query. And the reason is this approach also helps other less related answer increase its cosine similarity.

What's more, I found out that the given method could not break down an entire compound as two tokens. i.e. "super_testers" will be considered as "super". Based on this, I made a slight change in the code by splitting up the compounds into separate tokens. (See the comment of deal with compound, to split up into two words in DocumentVectorAnnotator.java)

Another **disadvantage** is that some morphological variants should not be removed in order to avoid the misunderstanding of sentence. Here is an example.

- "Apple iPods are the new..."→Apple
- "Apple picking season has ..." → apple
- "Apples are popular food ..." → apple
- "Apple sales were up in May." → ✍ apple or Apple

Therefore, stemming is expected to improve when users are tolerant of stemming mistakes because there are so many relevant documents. What's more, a good stem must be context-dependent, but it is too expensive to do when processing many documents.

```
cosine=0.2667   rank=2  qid=1   rel=1   In A.D. 79, long-dormant Mount V
cosine=0.4003   rank=1  qid=2   rel=1   When Michael Jordan--one of the
cosine=0.4714   rank=1  qid=3   rel=1   Alaska was purchased from Russia
cosine=0.3086   rank=1  qid=4   rel=1   On March 2, 1962, Wilt Chamberla
cosine=0.3062   rank=2  qid=5   rel=1   People of China have mixed feeli
cosine=0.5547   rank=2  qid=6   rel=1   Roger Bannister was the first to
cosine=0.1782   rank=3  qid=7   rel=1   And that's not even to mention t
cosine=0.3667   rank=2  qid=8   rel=1   Fighting for Holyfield's WBA hea
cosine=0.6529   rank=1  qid=9   rel=1   Luna 2 was the first spacecraft
cosine=0.8750   rank=1  qid=10  rel=1   Menchu won the Nobel peace prize
cosine=0.3536   rank=2  qid=11  rel=1   Devils Tower can be found in Cro
cosine=0.3953   rank=4  qid=12  rel=1   Named the "Mendocino Tree," the
cosine=0.2390   rank=3  qid=13  rel=1   Oregon's Crater Lake tops it at
cosine=0.5270   rank=1  qid=14  rel=1   Lionel Richiewas was lead singer
cosine=0.1455   rank=3  qid=15  rel=1   A new look at NASA satellite dat
cosine=0.4243   rank=1  qid=16  rel=1   Bob Marley died in 1981 from can
cosine=0.3769   rank=2  qid=17  rel=1   Corn futures found support from
cosine=0.2265   rank=2  qid=18  rel=1   From a single hamburger stand in
cosine=0.2820   rank=3  qid=19  rel=1   On May 6, 1937, the hydrogen-fil
cosine=0.4104   rank=1  qid=20  rel=1   They call it the Keystone State,
MRR=0.6541666666666667
```

2) Remove stop words

Stop words: Words that are discarded from a document representation.
• Typically function words: a, an, and, as, for, in, of, the, to, ...
By removing stop words, we could reduce index size significantly thus improving retrieval accuracy.

Nevertheless, it also has disadvantages.
Discarding stop words makes some queries difficult to satisfy, like “What is the keystone state? “. If we remove the stop words, it leaves only keystone and state. In this case, if the gold answer is quite long, its cosine similarity must be small.
Some other examples like “let it be or not”, will even leave nothing to retrieve. You can see from

```
cosine=0.0737   rank=3  qid=1   rel=1   In A.D. 79, long-dormant Mount V
cosine=0.1048   rank=3  qid=2   rel=1   When Michael Jordan--one of the
cosine=0.5303   rank=1  qid=3   rel=1   Alaska was purchased from Russia
cosine=0.3563   rank=1  qid=4   rel=1   On March 2, 1962, Wilt Chamberla
cosine=0.3441   rank=1  qid=5   rel=1   People of China have mixed feeli
cosine=0.2097   rank=2  qid=6   rel=1   Roger Bannister was the first to
cosine=0.2357   rank=1  qid=7   rel=1   And that's not even to mention t
cosine=0.4339   rank=2  qid=8   rel=1   Fighting for Holyfield's WBA hea
cosine=0.2649   rank=1  qid=9   rel=1   Luna 2 was the first spacecraft
cosine=0.7906   rank=1  qid=10  rel=1   Menchu won the Nobel peace prize
cosine=0.2500   rank=4  qid=11  rel=1   Devils Tower can be found in Cro
cosine=0.1443   rank=4  qid=12  rel=1   Named the "Mendocino Tree," the
cosine=0.3086   rank=3  qid=13  rel=1   Oregon's Crater Lake tops it at
cosine=0.5774   rank=1  qid=14  rel=1   Lionel Richiewas was lead singer
cosine=0.2222   rank=3  qid=15  rel=1   A new look at NASA satellite dat
cosine=0.5477   rank=1  qid=16  rel=1   Bob Marley died in 1981 from can
cosine=0.1907   rank=3  qid=17  rel=1   Corn futures found support from
cosine=0.0000   rank=2  qid=18  rel=1   From a single hamburger stand in
cosine=0.1066   rank=3  qid=19  rel=1   On May 6, 1937, the hydrogen-fil
cosine=0.3244   rank=1  qid=20  rel=1   They call it the Keystone State,
MRR=0.6500000000000001
```

its results that the MRR value REDUCES to 0.6500.

An increasingly common solution to this problem is to discard stop words from queries and occasionally leave them in the query if they are more than half the query terms or if user indicates that they should be retained. I’ve implemented this rule in this system, results of the given dataset show no difference by doing so, but I believe it do works in a bigger and complicated query set.

Another thing is about the stop word lists, which is always created manually. And the retrieval results also depend on its quality.

As for the given stop word lists, we could see some words like which, what, when, and they frequently appears in the query. In this case, if we remove them according to the rules for stop words, we would misunderstand the meaning of the query document, in a broad sense, it will lead to bad retrieval results.

3) Decompound: Split up compound into several words

By doing so, it increase some cosine similarity value and even higher its rank. For example, there is term “Jordan—one” in the second query sentence, and this approach increases its cosine to about 0.02. And I also successfully divided the following compounds.

```
[long, dormant]|2
[nba, record]|2
[169, 147]|2
[four, minute]|2
[4, minute]|2
[cool, think]|2
[800, year, old]|3
[370, foot, tall]|3
[singer, songwriter]|2
[above, normal]|2
[fast, food]|2
[hydrogen, fill]|2
[hindenburg, class]|2
```

The MRR value reaches 0.675 after accumulate all the methods and tricks above.

```
cosine=0.0722   rank=3  qid=1   rel=1   In A.D. 79, long-dormant Moun
cosine=0.1069   rank=3  qid=2   rel=1   When Michael Jordan--one of t
cosine=0.4714   rank=1  qid=3   rel=1   Alaska was purchased from Rus
cosine=0.3563   rank=1  qid=4   rel=1   On March 2, 1962, Wilt Chambe
cosine=0.3441   rank=1  qid=5   rel=1   People of China have mixed fe
cosine=0.4041   rank=1  qid=6   rel=1   Roger Bannister was the first
cosine=0.2357   rank=1  qid=7   rel=1   And that's not even to mentio
cosine=0.4339   rank=2  qid=8   rel=1   Fighting for Holyfield's WBA
cosine=0.6529   rank=1  qid=9   rel=1   Luna 2 was the first spacecra
cosine=0.7906   rank=1  qid=10  rel=1   Menchu won the Nobel peace pr
cosine=0.2500   rank=4  qid=11  rel=1   Devils Tower can be found in
cosine=0.3727   rank=4  qid=12  rel=1   Named the "Mendocino Tree," t
cosine=0.3086   rank=3  qid=13  rel=1   Oregon's Crater Lake tops it
cosine=0.5270   rank=1  qid=14  rel=1   Lionel Richiewas was lead sin
cosine=0.1455   rank=3  qid=15  rel=1   A new look at NASA satellite
cosine=0.5477   rank=1  qid=16  rel=1   Bob Marley died in 1981 from
cosine=0.1865   rank=3  qid=17  rel=1   Corn futures found support fr
cosine=0.0000   rank=2  qid=18  rel=1   From a single hamburger stand
cosine=0.1054   rank=3  qid=19  rel=1   On May 6, 1937, the hydrogen-
cosine=0.4104   rank=1  qid=20  rel=1   They call it the Keystone Sta
MRR=0.675
```

3. Better or different similarity measures:

1)Dice coefficient and Jaccard coefficient

Actually, they are quite similar to the cosine similarity. They are not metric.

2)unnormalized TF-IDF

As for the methods above, all terms are treated as equally important. TF-IDF introduces an idea of adding weight to some terms. Here is how we calculate normalized TF-IDF, and I implemented one removing the normalization. It is meaningful for some cases like the second query, since it increase its rank by increasing the weight of some query key words only show up in itself. Also, this unnormalized method partly solves over long length issue. And we could see

a lot of gold answer document with a long length, which gives rise to its bad rank if using normalization.

- "l": document term weight = log (tf) + 1
- "t": collection term weight = log (N / df)
- "c": cosine length normalization

$$\sqrt{\sum w_i^2}$$

- "n": weight = 1.0 (i.e., no normalization)
- For example:

Know this

$$\frac{\sum d_i \cdot q_i}{\sqrt{\sum d_i^2} \cdot \sqrt{\sum q_i^2}} = \frac{\sum \overbrace{(\log(tf)+1)}^{\text{"tf"}} \cdot \left(\overbrace{(\log(qtf)+1)}^{\text{"user weights"}} \overbrace{\log \frac{N}{df}}^{\text{"idf"}} \right)}{\underbrace{\sqrt{\sum (\log(tf)+1)^2}}_{\text{"doc length normalization"}} \cdot \underbrace{\sqrt{\sum \left((\log(qtf)+1) \log \frac{N}{df} \right)^2}}_{\text{"query length normalization"}}}$$

Cosine similarity metric

However, we could see a lot of zero similarity values, which means it has no words included in the query document. In this case, this method could not be a suitable one for this dataset. What's more, results showed that the high MRR is due to using the trick that highest relevant document has rank higher than others with the same similarity.

Further looking into the intermediate results, I found that some answer could hit because all of the candidate document has the same tf-idf value and according to our trick about tie that if we have two document with the same similarity value, we give our gold answer with a higher rank. So, I believe this tf-idf method is somewhat overfit for this dataset.

```
cosine=0.0000   rank=2  qid=1   rel=1   In A.D. 79, long-c
cosine=0.5883   rank=2  qid=2   rel=1   When Michael Jordc
cosine=0.9389   rank=1  qid=3   rel=1   Alaska was purchas
cosine=0.0000   rank=1  qid=4   rel=1   On March 2, 1962,
cosine=0.0000   rank=1  qid=5   rel=1   People of China hc
cosine=0.0000   rank=1  qid=6   rel=1   Roger Bannister wc
cosine=0.0000   rank=1  qid=7   rel=1   And that's not eve
cosine=2.4039   rank=1  qid=8   rel=1   Fighting for Holyf
cosine=0.0000   rank=1  qid=9   rel=1   Lunq 2 was the fir
cosine=0.0000   rank=1  qid=10  rel=1   Menchu won the Nob
cosine=0.2937   rank=3  qid=11  rel=1   Devils Tower can b
cosine=0.0000   rank=1  qid=12  rel=1   Named the "Mendoci
cosine=0.0000   rank=3  qid=13  rel=1   Oregon's Crater Lc
cosine=0.4592   rank=2  qid=14  rel=1   Lionel Richiewas v
cosine=0.0000   rank=1  qid=15  rel=1   A new look at NASA
cosine=0.0000   rank=1  qid=16  rel=1   Bob Marley died ir
cosine=0.0000   rank=1  qid=17  rel=1   Corn futures founc
cosine=0.0000   rank=1  qid=18  rel=1   From a single hamb
cosine=0.2865   rank=2  qid=19  rel=1   On May 6, 1937, th
cosine=1.7824   rank=1  qid=20  rel=1   They call it the M
MRR=0.8333333333333334
```

Based on this overfit issue, I slightly change the formula of calculating the tf-idf value by adding one to the idf value, and get a more reliable result by successfully removing some ties.

```
cosine=6.5785   rank=3  qid=1   rel=1   In A.D. 79, long-dormant Mount Vesuvius
cosine=12.8259  rank=1  qid=2   rel=1   When Michael Jordan--one of the greatest
cosine=8.0089   rank=2  qid=3   rel=1   Alaska was purchased from Russia in year
cosine=8.0905   rank=2  qid=4   rel=1   On March 2, 1962, Wilt Chamberlain score
cosine=3.0596   rank=1  qid=5   rel=1   People of China have mixed feelings abou
cosine=6.7418   rank=2  qid=6   rel=1   Roger Bannister was the first to break t
cosine=3.0228   rank=1  qid=7   rel=1   And that's not even to mention the breat
cosine=6.0177   rank=1  qid=8   rel=1   Fighting for Holyfield's WBA heavyweight
cosine=5.7198   rank=2  qid=9   rel=1   Luna 2 was the first spacecraft to reach
cosine=5.3025   rank=1  qid=10  rel=1   Menchu won the Nobel peace prize in 1992
cosine=-0.6625  rank=1  qid=11  rel=1   Devils Tower can be found in Crook Count
cosine=1.8722   rank=4  qid=12  rel=1   Named the "Mendocino Tree," the 600- to
cosine=0.2757   rank=1  qid=13  rel=1   Oregon's Crater Lake tops it at 1,932 fe
cosine=9.8539   rank=1  qid=14  rel=1   Lionel Richiemas was lead singer and son
cosine=5.5407   rank=2  qid=15  rel=1   A new look at NASA satellite data reveal
cosine=0.4374   rank=2  qid=16  rel=1   Bob Marley died in 1981 from cancer at a
cosine=3.1306   rank=3  qid=17  rel=1   Corn futures found support from forecast
cosine=0.2400   rank=1  qid=18  rel=1   From a single hamburger stand in San Ber
cosine=5.8633   rank=3  qid=19  rel=1   On May 6, 1937, the hydrogen-filled Gerr
cosine=6.5224   rank=1  qid=20  rel=1   They call it the Keystone State, and in
MRR=0.7125
```

2)BM25

BM25 is a bag-of-words retrieval function that ranks a set of documents based on the query terms appearing in each document, regardless of the inter-relationship between the query terms within a document (e.g., their relative proximity). Here is its score metric.
After utilizing this approach, I obtained the following results.

$$\text{score}(D,Q) = \sum_{i=1}^{n} \text{IDF}(q_i) \cdot \frac{f(q_i, D) \cdot (k_1 + 1)}{f(q_i, D) + k_1 \cdot (1 - b + b \cdot \frac{|D|}{\text{avgdl}})},$$

$$\text{IDF}(q_i) = \log \frac{N - n(q_i) + 0.5}{n(q_i) + 0.5}$$

```
cosine=-0.7263  rank=2  qid=1   rel=1   In A.D. 79, long-dormant Mount Vesu
cosine=0.0000   rank=1  qid=2   rel=1   When Michael Jordan--one of the gre
cosine=-5.0515  rank=3  qid=3   rel=1   Alaska was purchased from Russia in
cosine=-13.3896 rank=3  qid=4   rel=1   On March 2, 1962, Wilt Chamberlain
cosine=-7.6626  rank=3  qid=5   rel=1   People of China have mixed feelings
cosine=-9.6347  rank=3  qid=6   rel=1   Roger Bannister was the first to br
cosine=-2.8654  rank=4  qid=7   rel=1   And that's not even to mention the
cosine=-7.6505  rank=4  qid=8   rel=1   Fighting for Holyfield's WBA heavyw
cosine=-8.5812  rank=4  qid=9   rel=1   Luna 2 was the first spacecraft to
cosine=-6.7293  rank=4  qid=10  rel=1   Menchu won the Nobel peace prize in
cosine=-8.3741  rank=4  qid=11  rel=1   Devils Tower can be found in Crook
cosine=-9.0645  rank=4  qid=12  rel=1   Named the "Mendocino Tree," the 600
cosine=-7.4488  rank=3  qid=13  rel=1   Oregon's Crater Lake tops it at 1,9
cosine=-1.7855  rank=2  qid=14  rel=1   Lionel Richiewas was lead singer an
cosine=-2.6887  rank=1  qid=15  rel=1   A new look at NASA satellite data r
cosine=-8.5024  rank=3  qid=16  rel=1   Bob Marley died in 1981 from cancer
cosine=-4.5603  rank=3  qid=17  rel=1   Corn futures found support from for
cosine=-3.5445  rank=1  qid=18  rel=1   From a single hamburger stand in Sa
cosine=-4.5632  rank=3  qid=19  rel=1   On May 6, 1937, the hydrogen-filled
cosine=-7.3847  rank=3  qid=20  rel=1   They call it the Keystone State, an
MRR=0.48639455782312924
```

Observing its results shows its IDF doesn't give a positive impact on the dataset. Furthermore, since there are several methods to calculate the IDF, this inspired me I added one when calculating the IDF. After that, MRR reaches 0.7823, and we have hit 12 correct selected documents.

```
cosine=0.9880   rank=1  qid=1   rel=1   In A.D. 79, long-dormant Mount Vesuvius eru
cosine=3.0961   rank=1  qid=2   rel=1   When Michael Jordan--one of the greatest ba
cosine=1.9885   rank=1  qid=3   rel=1   Alaska was purchased from Russia in year 18
cosine=-5.3182  rank=3  qid=4   rel=1   On March 2, 1962, Wilt Chamberlain scored a
cosine=-0.2501  rank=1  qid=5   rel=1   People of China have mixed feelings about
cosine=-2.4000  rank=3  qid=6   rel=1   Roger Bannister was the first to break the
cosine=2.2073   rank=1  qid=7   rel=1   And that's not even to mention the breathta
cosine=-0.6867  rank=1  qid=8   rel=1   Fighting for Holyfield's WBA heavyweight ti
cosine=-0.5629  rank=3  qid=9   rel=1   Luna 2 was the first spacecraft to reach th
cosine=2.7562   rank=1  qid=10  rel=1   Menchu won the Nobel peace prize in 1992.
cosine=-4.5629  rank=4  qid=11  rel=1   Devils Tower can be found in Crook County
cosine=-4.9391  rank=4  qid=12  rel=1   Named the "Mendocino Tree," the 600- to 800
cosine=-3.6209  rank=3  qid=13  rel=1   Oregon's Crater Lake tops it at 1,932 feet
cosine=7.8736   rank=1  qid=14  rel=1   Lionel Richiewas was lead singer and songwr
cosine=1.0584   rank=1  qid=15  rel=1   A new look at NASA satellite data revealed
cosine=-2.7088  rank=3  qid=16  rel=1   Bob Marley died in 1981 from cancer at age
cosine=-0.8478  rank=1  qid=17  rel=1   Corn futures found support from forecasts f
cosine=-1.7230  rank=1  qid=18  rel=1   From a single hamburger stand in San Bernar
cosine=-0.8483  rank=2  qid=19  rel=1   On May 6, 1937, the hydrogen-filled German
cosine=0.2053   rank=1  qid=20  rel=1   They call it the Keystone State, and in thi
MRR=0.7823129251700679
```

Why this have a good result?
1. every word has a weight
2. it considers the length of a document
3. tie rule

Since I still found out some pseudo good results based on our tie rules, I tried to slightly change the formula and makes it more reliable. What I found out is that the parameters in the formula is quite important to fit this dataset.
Here is the result of various parameters for the BM25 formula.

The Okapi BMxx model

$$\sum_{t \in q} \underbrace{\left(\log \frac{N - df_t + 0.5}{df_t + 0.5} \right)}_{\text{RSJ weight (idf)}} \underbrace{\frac{tf_t}{tf_t + k_1\left((1-b) + b\frac{doclen}{avg\_doclen}\right)}}_{\text{tf weight}} \underbrace{\frac{(k_3+1)\,qtf_t}{k_3 + qtf_t}}_{\text{user weight}}$$

BMxx indicates different parameter settings

- **Originally:** k_1=2, b=0.75, k_3=0 (also used in Inquery)
- **BM25:** k_1=1.2, b=0.75, k_3=0-1000
  k_1=0.9, b=0.40, k_3=0-1000 (large collections)*

	b=0.75
k1=0.9	0.7823
k1=1.2	0.7823
k1=2.0	0.7823

Although, I didn't see any change if slightly adjusting the parameters, I found out that the score changes, and the k1=2.0 makes the least number of ties.

3) cosine similarity

Finally, I returned to the cosine similarity approach. Here is the results after removing the unre-

```
cosine=0.1443   rank=3   qid=1   rel=1   In A.D. 79, long-dormant Mour
cosine=0.1543   rank=3   qid=2   rel=1   When Michael Jordan--one of t
cosine=0.4714   rank=1   qid=3   rel=1   Alaska was purchased from Rus
cosine=0.4454   rank=1   qid=4   rel=1   On March 2, 1962, Wilt Chambe
cosine=0.5735   rank=1   qid=5   rel=1   People of China have mixed fe
cosine=0.4041   rank=1   qid=6   rel=1   Roger Bannister was the first
cosine=0.3354   rank=1   qid=7   rel=1   And that's not even to mentic
cosine=0.4339   rank=2   qid=8   rel=1   Fighting for Holyfield's WBA
cosine=0.6529   rank=1   qid=9   rel=1   Luna 2 was the first spacecra
cosine=0.7906   rank=1   qid=10  rel=1   Menchu won the Nobel peace pr
cosine=0.5000   rank=1   qid=11  rel=1   Devils Tower can be found in
cosine=0.3727   rank=4   qid=12  rel=1   Named the "Mendocino Tree," t
cosine=0.3086   rank=3   qid=13  rel=1   Oregon's Crater Lake tops it
cosine=0.5270   rank=1   qid=14  rel=1   Lionel Richiewas was lead sir
cosine=0.1455   rank=3   qid=15  rel=1   A new look at NASA satellite
cosine=0.5477   rank=1   qid=16  rel=1   Bob Marley died in 1981 from
cosine=0.1865   rank=3   qid=17  rel=1   Corn futures found support fr
cosine=0.0778   rank=3   qid=18  rel=1   From a single hamburger stand
cosine=0.1054   rank=3   qid=19  rel=1   On May 6, 1937, the hydrogen-
cosine=0.4104   rank=1   qid=20  rel=1   They call it the Keystone Sta
MRR=0.7041666666666668
```

lated punctuations and using stem function. There is almost no tie, and the results is more reliable.

4) evaluate the above three methods by p-value:

In statistical significance testing, the p-value is the probability of obtaining a test statistic result at least as extreme or as close to the one that was actually observed, assuming that the null hypothesis is true. A researcher will often "reject the null hypothesis" when the p-value turns out to be less than a predetermined significance level, often 0.05. Such a result indicates that the observed result would be highly unlikely under the null hypothesis. It is quite similar to other statistical method like, student's t-test.

Here is a statement of how math lab compute the p-value. x,y is the vector of the score value o calculated by each method in the report file.

x=[6.5785, 12.8259, 8.0089,…..,6.5224]

[h,p,ci,stats] = ttest2(x,y)

From its result, I know that the p-value for every two methods is more than 0.5, so I could say that we could not know the reality of these results.

4.Follow-up Thoughts for Improvement:

1.Provide a inverted lists:

The above methods have not considered the relative position two words. For example, some disturbing candidate words have a good result only if they show up. However, they might in a meaningless order.

i.e.
Does Mary love John?
answer 1: Mary loves John.
answer 2: John loves Mary.
If we use the mentioned measures to score, we will have the same score for these two answers. However, they are actually quite difference from the meaning perspective.
To improve this, we could store an relative position for each candidate token. For example, they those three tokens exist in two answers, we rank the first one higher because the tokens have an order the same as the query.
Another problem also comes up if we are doing so, like John is loved by Mary. In this case, although the order is different, it still should be considered as the correct answer. Based on this, we need a smarter stemming method that should think of this condition when turing "loved" to "love".

2. Morphological variants mismatched issue:

i.e.
```
qid=13     rel=99     How deep is Crater Lake?
qid=13     rel=1      Oregon's Crater Lake tops it at 1,932 feet at its
greatest depth.
```
From this example, we could see that deep could not be consider the same as depth based on our methods. Because the stem method only care about some morphological variants like tense variants. And it could not recognize token like depth and deep as the same.

3. Vocabulary mismatched issue:

1) **paraphrase:** By scanning the datasets, I found out a lot of gold answers has tokens paraphrasing those in its query document.

For example.
```
qid=9 rel=99     What was the first spaceship on the moon
qid=9 rel=1 Luna 2 was the first spacecraft to reach the surface of
the Moon.
```
However, our temporary approach could not recognize tokens with the same meaning. What's more the meaning needs a context-based solution, which has a great cost.

2) Phrase Recognition Methods: Part of Speech Tagging

Different words might have the same meaning, while one word could have multiple meaning, and also many part of speech.
By storing each word's part of speech information, we could partly put the token's context into consideration.
i.e. I/NN love/VV this/NN great/JJ city/NN.

4. Formula and parameters Impact

There are several interpretations for IDF and slight variations on its formula. Slightly changing its formula like use log(term frequency)+1, or just use term frequency leads to various results. Some results are overfit for this dataset because of the tie rules.

What's more, I noted that the formula for IDF that I used shows potentially major drawbacks since most of terms appearing in **more than half of the corpus documents**. These terms' IDF is negative, so for any two almost-identical documents, one which contains the term and one which does not contain it, the latter will possibly get a larger score. This means that terms appearing in more than half of the corpus will provide negative contributions to the final document score. This is often an undesirable behavior, so many real-world applications would deal with this IDF formula in a different way.

Again, in the calculation of BM25 derivation, the parameters of k1 and b value don't make any change to the final result, but slightly changes each score.

5. Stem method introduce some drawbacks

With both stemming method and BM25, I have the following results if I didn't remove "'" for the "devil'" in each answer document. As you can see, it has four answers with the same score, and due to our tie rule, we make the the relevant one the highest.

```
i.e. devil tower can be find in crook county
to the west across the wyome border be the staggeringly beautiful de-
vil' tower national monument
devil' tower be an igneous intrusion that rise dramatically 1267 foot
(386 m) above the surround terrain
in 1941 petzoldt join other rock climber to rescue a maroon parachu-
tist who have land atop devil' tower
what be the height of the tallest redwood
goldbm in gold query: -2.2809345280805604
answerbm in answer: -2.2809345280805604
answerbm in answer: -2.2809345280805604
answerbm in answer: -2.2809345280805604
```

After removing “‘”, MRR reduces because now every candidate could hit “devil”, and the each

```
cosine=0.9880   rank=1  qid=1   rel=1   In A.D. 79, long-dormant Mount Vesuvi
cosine=3.0961   rank=1  qid=2   rel=1   When Michael Jordan--one of the great
cosine=1.9885   rank=1  qid=3   rel=1   Alaska was purchased from Russia in y
cosine=-5.3182  rank=3  qid=4   rel=1   On March 2, 1962, Wilt Chamberlain sc
cosine=-0.2501  rank=1  qid=5   rel=1   People of China have mixed feelings c
cosine=-2.4000  rank=3  qid=6   rel=1   Roger Bannister was the first to brec
cosine=2.2073   rank=1  qid=7   rel=1   And that's not even to mention the br
cosine=-0.6867  rank=1  qid=8   rel=1   Fighting for Holyfield's WBA heavywei
cosine=-0.5629  rank=3  qid=9   rel=1   Luna 2 was the first spacecraft to re
cosine=2.7562   rank=1  qid=10  rel=1   Menchu won the Nobel peace prize in 1
cosine=-4.5629  rank=4  qid=11  rel=1   Devils Tower can be found in Crook Co
cosine=-4.9391  rank=4  qid=12  rel=1   Named the "Mendocino Tree," the 600-
cosine=-3.6209  rank=3  qid=13  rel=1   Oregon's Crater Lake tops it at 1,932
cosine=7.8736   rank=1  qid=14  rel=1   Lionel Richiewas was lead singer and
cosine=1.0584   rank=1  qid=15  rel=1   A new look at NASA satellite data rev
cosine=-2.7088  rank=3  qid=16  rel=1   Bob Marley died in 1981 from cancer c
cosine=-0.8478  rank=1  qid=17  rel=1   Corn futures found support from forec
cosine=-1.7230  rank=1  qid=18  rel=1   From a single hamburger stand in San
cosine=-0.8483  rank=2  qid=19  rel=1   On May 6, 1937, the hydrogen-filled C
cosine=0.2053   rank=1  qid=20  rel=1   They call it the Keystone State, and
MRR=0.7823129251700679
```

score slightly changes. But, I believe this result is more reliable for a common dataset.

6. misspelling

There are some errors because of misspelling.

i.e. qid=7 rel=0 Aaska is a U.S. state situated in the northwest extremity of the North American continent.

Based on this, I tried to use lingpipe’s spelling corrector. I used the given model, and found out it would not have a better performance for the misspelling words in our document. Here is the results. I also tried to add training documents into its dataset in order to obtain a new model. However, it still doesn’t improve.

```
>Alaska
Found 32 document(s) that matched query 'Alaska':
Found 32 document(s) matching best alt='alaska':

>aaska
Found 0 document(s) that matched query 'aaska':
Found 0 document(s) matching best alt='was a':

>pompei
Found 0 document(s) that matched query 'pompei':
Found 1125 document(s) matching best alt='hockey':

>pompeii
Found 4 document(s) that matched query 'pompeii':
 No spelling correction found.

>allaska
Found 0 document(s) that matched query 'allaska':
Found 32 document(s) matching best alt='alaska':
```

You could check my github link https://github.com/eyrelzy/hw3-zhiyuel to see how lingpipe's corrector works.

7. normalization and unnormalized

I found out an interesting intermediate results that although our gold answer has more words matched, but still got a low rank because of over long length. In this case, we could consider other ways instead of normalization, like Pivoted Document Length Normalization.

Pivoted Document Length Normalization: Lnu.Ltu

Lnu.Ltu: A pivoted vector space similarity metric

- **"L":** document term weight = $\frac{\log(tf)+1}{\log(\text{avg } tf \text{ in doc})+1}$
- **"t":** collection term weight = log (N / df)
- **"u":** pivoted unique normalization = $\frac{1}{0.8\times+0.2\times\frac{\text{Num Unique Terms}}{\text{Avg Num Unique Terms}}}$
- **"n":** weight = 1.0 (i.e., no normalization)
- **For example:**

$$\frac{\sum d_i \cdot q_i}{\sqrt{\sum d_i^2}\cdot\sqrt{\sum q_i^2}} = \frac{\sum(\overbrace{L_{d_i}\times n_{d_i}}^{\text{"tf"}})\cdot(\overbrace{L_{q_i}\times t_{q_i}}^{\text{"idf"}})}{\underbrace{u_{d_i}}_{\text{"doc length normalization"}}\cdot\underbrace{u_{q_i}}_{\text{"query length normalization"}}}$$

8. These mentioned methods all have not thought of the meaning of the query and its answers.

To improve this, we need some methods based on the context. For example, if the query asked for "when", we could give a bigger weight for answer containing "in" or numbers like "1967". However, although it will have a good result for those queries that are asking something, this method is likely to be overfit to those dataset.

5 Reference

1.BM25:
http://en.wikipedia.org/wiki/Okapi_BM25
2.LingPipe spelling corrector
http://alias-i.com/lingpipe/demos/tutorial/querySpellChecker/read-me.html
3. p-value
http://en.wikipedia.org/wiki/P-value
4.TF-IDF
11-442 / 11-642 search engine courseware