CS410 Project Report

Search Engine for Video Segment Search of CS410 Lecture Videos

1 Team Information

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Project work contribution: Wusi Chen (100% contribution)

2 Introduction and Work Overview

In this project, a search engine application is built that can support the segment search of CS410 lecture video on Coursera. With this search engine, the learners of this course can find the relevant video segment of the lectures to their queries, and can play the lecture video from the beginning of the segments in Coursera. This can improve the learning experience of this course, since this search engine can save learner's time in watching unrelated course videos before they find the relevant video segments.

Although Coursera has a search bar on the top of their webpages which can find the relevant video segments, that search engine can only return the video segments whose transcript matches all the query terms. For example, the search engine in Coursera returns no result if the query is "bag of word entropy", as shown in Figure 1. This unannounced restriction/limitation can deteriorate the learning experience, since as the people who do not have a full understanding of the knowledge of this course, the learners may not know if the terms in their queries do not happen at the same time in transcript segments.

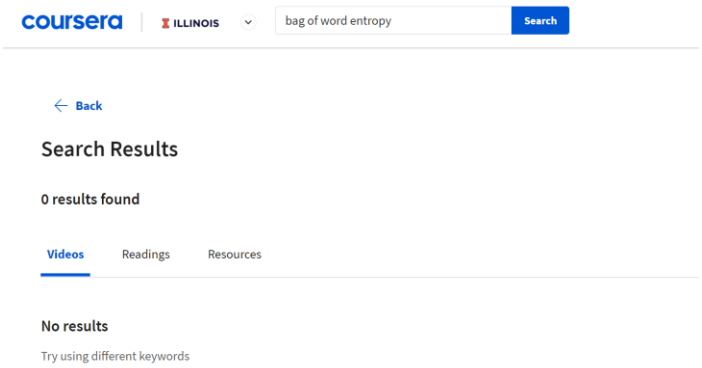


Figure 1 Search result of "bag of word entropy" from Coursera

The work of this project can be divided into 2 parts. The first part is to build a Python program which processes the subtitle files (vtt files) downloaded from Coursera. This program divides the lecture videos into segments, and stores the data of the video segments into a format which is compatible to search engine application for ranking relevant video segments and retrieving their information. The second part is to build a Python-based web application to provide the learners a user-friendly interface to enter queries, and to see a list of relevant video segments with their transcript and links to play the lecture video from the beginning of the video segments in Coursera.

3 Application Usage
3.1 Installation

To install the search engine application for video segment search, Python 3.7.0 shall be installed to the machine, and the project files can be cloned from GitHub using the following command:

```
git clone https://github.com/chenwusi2012/torrey_pines
cd .\torrey_pines
```

The following Python libraries shall be installed to run the project code:

- webvtt-py: To parse the subtitle files of the lecture videos downloaded from Coursera.
- Metapy: To create an inverted index for the transcript segments, and to rank the relevant transcript segments to the queries.
- Pandas: To manipulate the data of all the video segments, and to save or load the data from CSV files.
- pytoml: To read the file config.toml in the project directory.
- Bottle: To provide the website framework for search engine website.

The text file requirements.txt is provided in the project directory. To install the above Python libraries automatically, run the following command under the project directory:

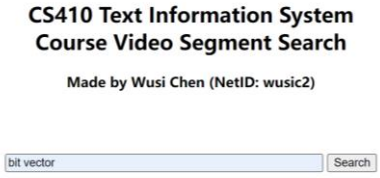
```
pip install -r requirements.txt
```

To launch the search engine application (website), run the following command under the project directory:

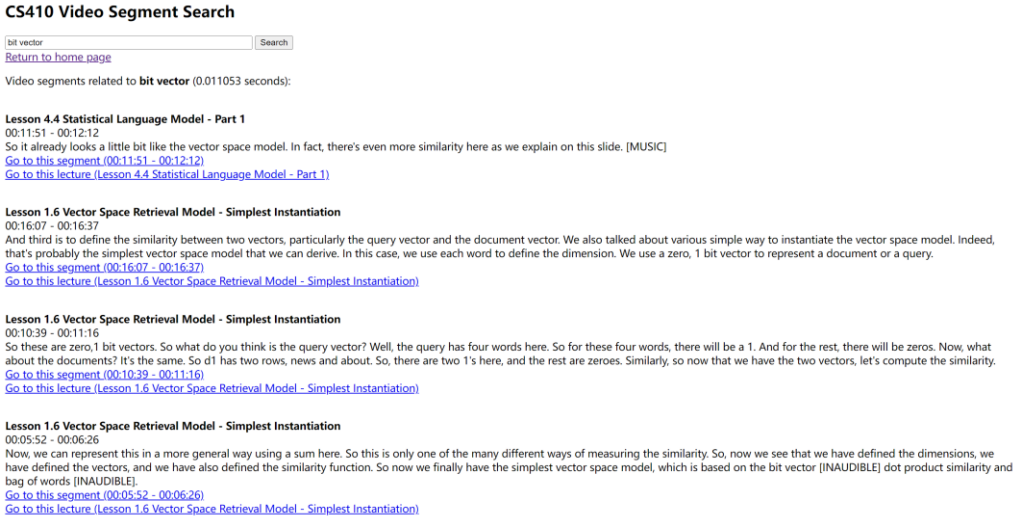
```
python ./bottle_app.py.
```

3.2 Use

After the launch of the search engine application, the users can go to the home page through this URL: http://localhost:8080/. If the search engine application/website is deployed to a public URL, the users can go to the home page using the public URL. At the home page, the users can use the application like Goggle. The users can type a query in the input box, as shown in Figure 2 (a). After clicking the search button, the users can see a list of relevant video segments, each of which has the lecture name, start timestamp, end timestamp, and transcript, as shown in Figure 2 (b). At the end of each returned video segment, 2 hyperlinks are provided. By clicking the link “Go to this segment,” the users can go to the corresponding video segment in Coursera, and the time of the video player in Coursera is set to the start timestamp of the segment. By clicking the link “Go to this lecture”, the users can go to the lecture video in Coursera, and play the lecture video from the beginning of the lecture. From the page of search result, the users can start another search by entering a new query to the input box at the top of the webpage, and clicking the search button.



(a)



(b)

Figure 2 (a) Home page of search engine website of CS410 video segments (b) Sample search result.

4 Implementation

4.1 Parser (parser.py)

The purpose of the parser is to process the subtitle files (vtt files) for CS410 course lecture videos, and to save the data into the file format which is compatible to Metapy python library and the search engine application. The transcript in the subtitle files is separated into segments. The length of each transcript segment is defined by the time duration of the corresponding video segment. Each transcript segment is extracted and saved when the time duration of the corresponding video segment is no less than a threshold (The current setting is 30s).

There are 2 types of input files for the parser. The first type of input files is the subtitles files (vtt files) downloaded from Coursera website and saved in the subtitle folder. The screenshot of a sample subtitle file is shown in Figure 3 (a). The second type of the input files is link_info.csv in the dataset folder. This CSV file is manually prepared, and has 2 columns, as shown in Figure 3 (b). The first column is the name of all the lecture videos, which is also the names of all the subtitle

files (vtt files), and the second column is the lecture identification code of all the lecture videos. The identification code is unique for each of the lecture video, and the link of a lecture video is “https://www.coursera.org/learn/cs-410/lecture/” followed by the identification code of that video.

```
WEBVTT

1
00:00:00.000 --> 00:00:05.293
[MUSIC]

2
00:00:10.067 --> 00:00:15.310
In this lecture, we continue
the discussion of vector space model.

3
00:00:15.310 --> 00:00:18.810
In particular, we're going to
talk about the TF transformation.

4
00:00:18.810 --> 00:00:20.100
In the previous lecture,

5
00:00:20.100 --> 00:00:25.880
we have derived a TF idea of weighting
formula using the vector space model.

6
```

(a)

lecture	id
Lesson 1.1 Natural Language Content Analysis	rLpwp
Lesson 1.2 Text Access	OvxTu
Lesson 1.3 Text Retrieval Problem	CXoWB
Lesson 1.4 Overview of Text Retrieval Methods	gxXq6
Lesson 1.5 Vector Space Model - Basic Idea	o8WNd
Lesson 1.6 Vector Space Retrieval Model - Simplest Instantiation	dM6kh
Lesson 2.1 Vector Space Model - Improved Instantiation	7jqJI
Lesson 2.2 TF Transformation	W0NZe
Lesson 2.3 Doc Length Normalization	RnXhr
Lesson 2.4 Implementation of TR Systems	2Cbq9
Lesson 2.5 System Implementation - Inverted Index Construction	PgzsP
Lesson 2.6 System Implementation - Fast Search	QKK7y
Lesson 3.1 Evaluation of TR Systems	YSvkh
Lesson 3.2 Evaluation of TR Systems - Basic Measures	VMh3Z
Lesson 3.3 Evaluation of TR Systems - Evaluating Ranked Lists - Part 1	rU7LT
Lesson 3.4 Evaluation of TR Systems - Evaluating Ranked Lists - Part 2	8Q2Tw
Lesson 3.5 Evaluation of TR Systems - Multi-Level Judgements	uGa00
Lesson 3.6 Evaluation of TR Systems - Practical Issues	thRNy
Lesson 4.1 Probabilistic Retrieval Model - Basic Idea	nkg5n
Lesson 4.2 Statistical Language Model	kv4Aj

(b)

Figure 3 (a) Sample subtitle file (Lesson 2.2 TF Transformation); (b) Head of link_info.csv

There are 2 output files from the parser. The first output file is data.csv in the dataset folder. This CSV file contain the data of all the parsed video segments, including their start and end timestamps, lecture name, lecture identification code, and transcript, as shown in Figure 4. The second output file is cs410.dat file in the cs410 folder. Each line in this file is the transcript of one video segment. This file is used for creating the inverted index through Metapy python library.

	lecture	lecture_id	start_time	end_time	text
0	Lesson 1.1 Natural Langu	rLpwp	0:00:00	0:00:32	[SOUND] >> This lecture is about Natural Language of Content Analysis. As you see
1	Lesson 1.1 Natural Langu	rLpwp	0:00:32	0:01:05	We're going to cover three things. First, what is natural language processing, whicl
2	Lesson 1.1 Natural Langu	rLpwp	0:01:06	0:01:42	Now what do you have to do in order to understand that text? This is basically wh
3	Lesson 1.1 Natural Langu	rLpwp	0:01:42	0:02:15	So that's the first step. After that, we're going to figure out the structure of the se
4	Lesson 1.1 Natural Langu	rLpwp	0:02:16	0:02:51	So here we show we have noun phrases as intermediate components, and then ve
5	Lesson 1.1 Natural Langu	rLpwp	0:02:51	0:03:23	For example, you might imagine a dog that looks like that. There's a boy and there
6	Lesson 1.1 Natural Langu	rLpwp	0:03:25	0:03:56	Now from this representation we could also further infer some other things, and w
7	Lesson 1.1 Natural Langu	rLpwp	0:03:56	0:04:29	You can even go further to understand why the person say at this sentence. So this
8	Lesson 1.1 Natural Langu	rLpwp	0:04:29	0:05:01	That could be one possible intent. To reach this level of understanding would requ
9	Lesson 1.1 Natural Langu	rLpwp	0:05:01	0:05:33	Computers unfortunately are hard to obtain such understanding. They don't have s
10	Lesson 1.1 Natural Langu	rLpwp	0:05:33	0:06:05	For example, programming languages. Those are harder for us, right? So natural la
11	Lesson 1.1 Natural Langu	rLpwp	0:06:05	0:06:36	We could overload the same word with different meanings without the problem. E
12	Lesson 1.1 Natural Langu	rLpwp	0:06:39	0:07:13	The word of root may have multiple meanings. So square root in math sense or the
13	Lesson 1.1 Natural Langu	rLpwp	0:07:16	0:07:54	So this is an example of synaptic ambiguity. What we have different is structures t
14	Lesson 1.1 Natural Langu	rLpwp	0:07:55	0:08:27	Another example of difficulty is anaphora resolution. So think about the sentence .
15	Lesson 1.1 Natural Langu	rLpwp	0:08:27	0:09:00	It would have to use a lot of knowledge to figure that out. It also would have to ma
16	Lesson 1.1 Natural Langu	rLpwp	0:09:01	0:09:33	We can do part of speech tagging pretty well, so I showed 97% accuracy here. Nov

Figure 4 Head of data.csv

The parser does the follow to process the subtitle files (The flowchart is shown in Figure 10 (a) in Appendix **on the last page**):

- Create a Pandas dataframe for collecting segment data, named “output_df”.
- Load link_info.csv as a Pandas dataframe, named “link_df”.
- Iterate the rows in the Pandas dataframe “link_df” to iterate all the subtitle files.

- For each row, read the lecture name and lecture identification code, and identify the corresponding vtt file in the subtitle folder.
- Read the found vtt file using webvtt-py library. This library reads the captions in the vtt file line by line.
    - For each line in the vtt file, get the start timestamp, end timestamp, and caption. If the caption does not stop at a period ".", save the caption as the transcript of the segment, and read the next line. Save the start timestamp as the start timestamp of a video segment.
    - Keep reading the next lines. Append the caption to the transcript of this segment (accumulate the transcript of the segment). Keep updating the end timestamp of this segment.
    - If one line stops at a period ".", check the time difference between the start timestamp and end timestamp of the segment. If the time difference is less than the threshold (the current setting is 30 seconds), keep reading more lines until the next period ".". If the time difference is more than the threshold, save the lecture name, lecture identification code, start timestamp, end timestamp, and transcript of the current segment to the Pandas dataframe "output_df". Besides, save the transcript of the segment to a line in cs410.dat.
- After iterating all the rows in the Pandas dataframe "link_df", save the Pandas dataframe "output_df" with the segment data to data.csv.
- Create an inverted index for all the transcript segments in cs410.dat using Metapy python library (remove the existed inverted index if the folder "idx" already exists).

After running the parser (parser.py), 96 lecture videos are processed (96 vtt subtitle files), and the transcript of all the lecture videos is separated into 2188 segments. The data of the all the segment is stored into the 2 output files.

4.2 Search Engine Application (bottle_app.py)

The purpose of the search engine application is to provide a user-friendly interface for searching course video segments related to users' queries. The website for search engine application is built based on the Python micro web-framework Bottle (Initially, Flask was chosen as the web framework for search engine application. However, the python program gets stuck and runs forever when it calls "ranker.score" method from Metapy python library). In bottle_app.py, the functions with a route() decorators are callback functions, as shown in Figure 5. When a URL path inside route() is called, the corresponding callback function is executed.

```
@route('/')
def root():
    print("Home page")
    return template('home')


@route('/search', method='POST')
def search():
    a = datetime.datetime.now()
    is_empty = False
    print("Result page")
    query = request.forms.get('query')
    query = query.strip()
```

Figure 5 Callback Function in bottle_app.py

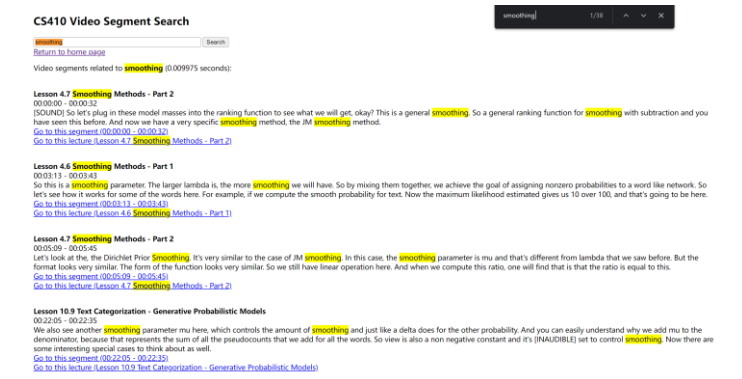
When a user calls the URL path "/" (http://localhost:8080/), and the callback function "root" is called, which renders the home page with the template home.tpl in the views folder. This template has a form HTML element which can collect the user's query through the input box. When the user clicks the search button, the URL path "/search" is called (http://localhost:8080/search), and the callback function "search" is called according. The function leverages Metapy python library to find relevant video segments to the users' query, and renders the template result.tpl in the view folder to display the information of the returned video segments on the webpage.

In detail, after the users click the search button in the home page, the callback function "search" does the following actions (The flowchart is shown in Figure 10 (b) in Appendix **on the last page**):

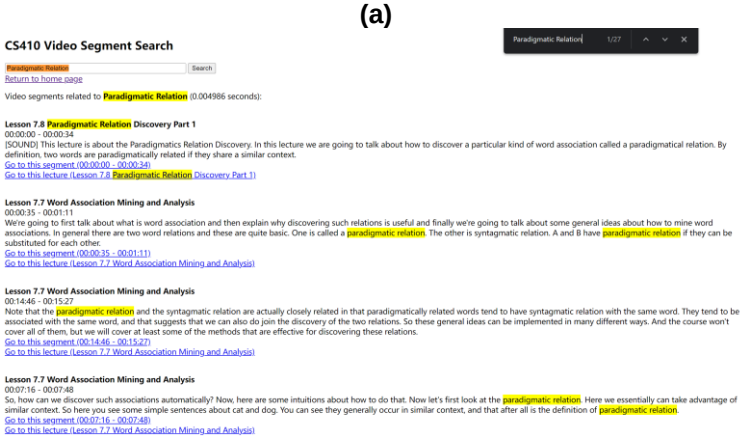
- Load data.csv in the dataset folder to a Pandas dataframe (this is done when the search engine application is launched).
- Get the query from the form element from the home.tpl.
- Call the defined "rank" function. This function leverages Metapy python library to return a list of the indexes of the relevant video segments.
- Using the returned indexes, collect the full information of the returned video segments from the Pandas dataframe. For each returned video segment:
    - Get the lecture name, lecture identification code, start timestamp, end timestamp, transcript of the video segment from the Pandas dataframe.
    - Form the link of the lecture video, which is "https://www.coursera.org/learn/cs-410/lecture/" followed by the lecture identification code.
    - Form the link to the video segment, which is "https://www.coursera.org/learn/cs-410/lecture/" followed by the lecture identification code, a string "?t=", and the start time of the video segment in seconds. The start time is calculated through the function "convert_time". For example, if a segment in lecture 9.6 (the lecture identification code is N5cBh) starts at 3:59, the link to this video segment is https://www.coursera.org/learn/cs-410/lecture/N5cBh?t=239.
    - Save the information of the video segment as a dictionary "segment".
    - Append the dictionary "segment to the list "result", which contains the information of all the returned video segments.
- Render the search result webpage with the template result.tpl in the views folder. Pass the string "query" and the list "result" to the template.

5 Demonstration of Functionality

The search result screenshots for several queries are shown in Figure 6. The query terms are highlighted by the web browser (Ctrl + F, and type the query). From the screenshots, we can see that the search engine application can return the relevant video segments whose transcript contains the query terms. Section 6 includes the performance evaluation for more queries.



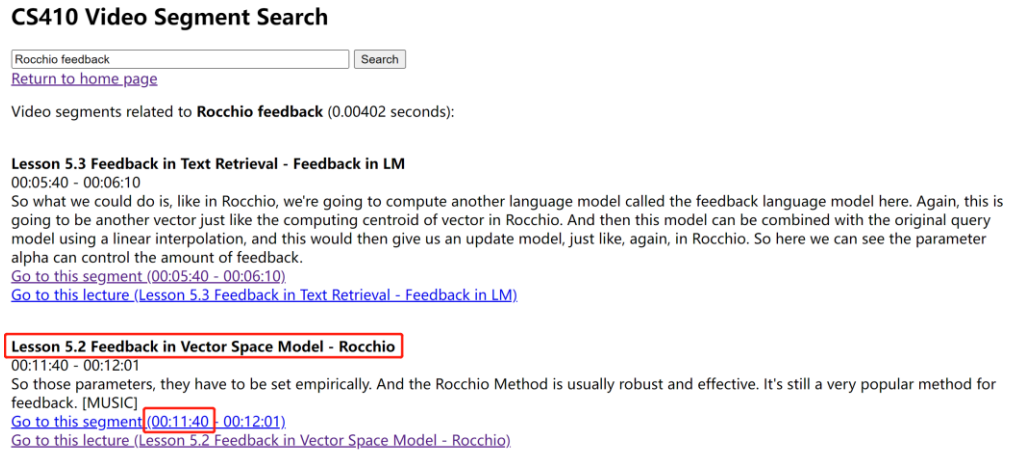
(a)



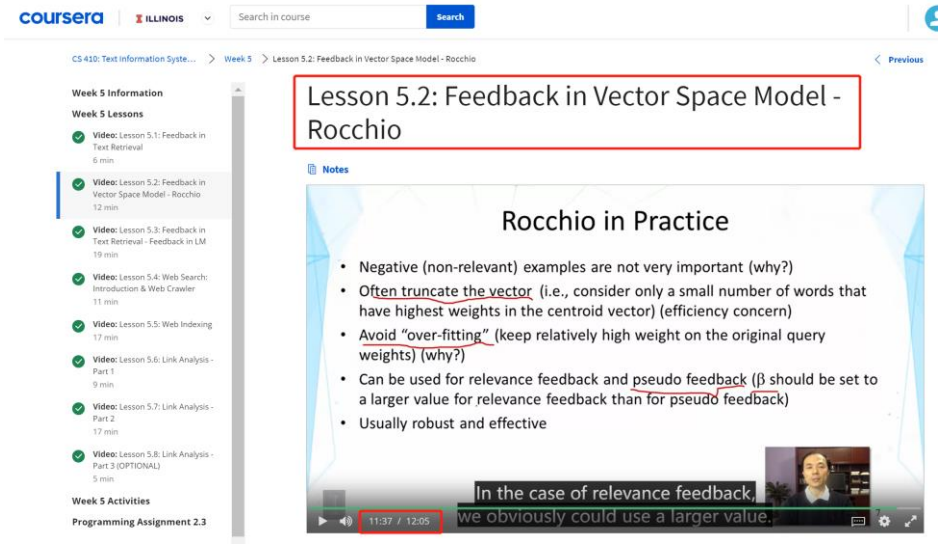
(b)

Figure 6 (a) Search result for query "smoothing"; (b) Search result for query "paradigmatic relation". Query terms highlighted by web browser

As shown in Figure 7, when the users click the link "Go to this segment" for one of the returned video segments, the webpage of the corresponding lecture in Coursera is shown, and the start time of the video player is set to the start timestamp of the corresponding video segment minus 3 seconds (Coursera minus 3 seconds from the start timestamp of the video segment to make sure the viewers can see the start of the video segment without missing any transcript).



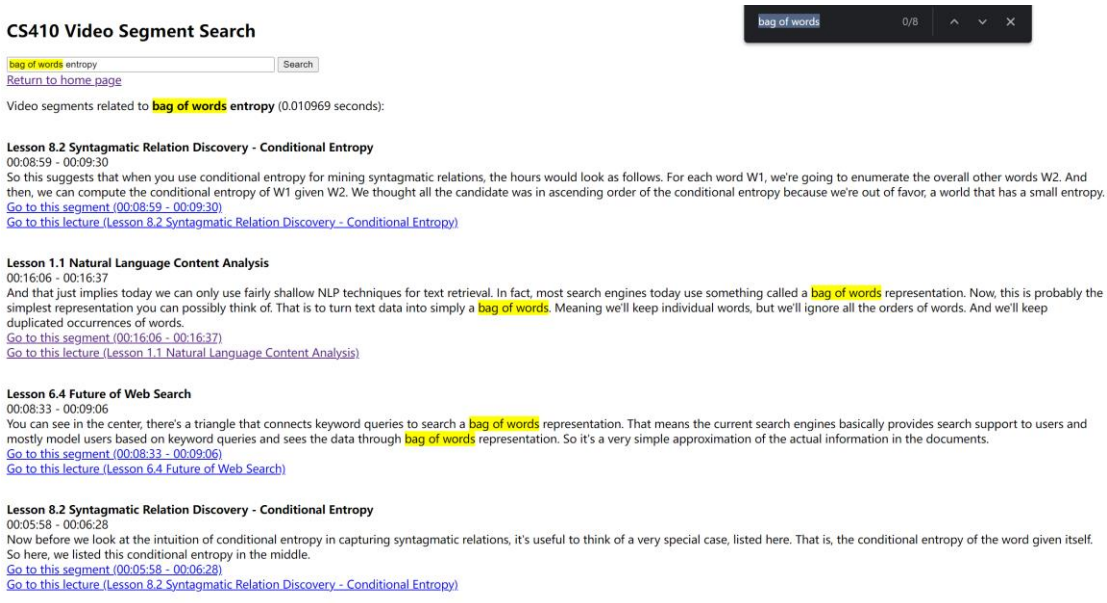
(a)



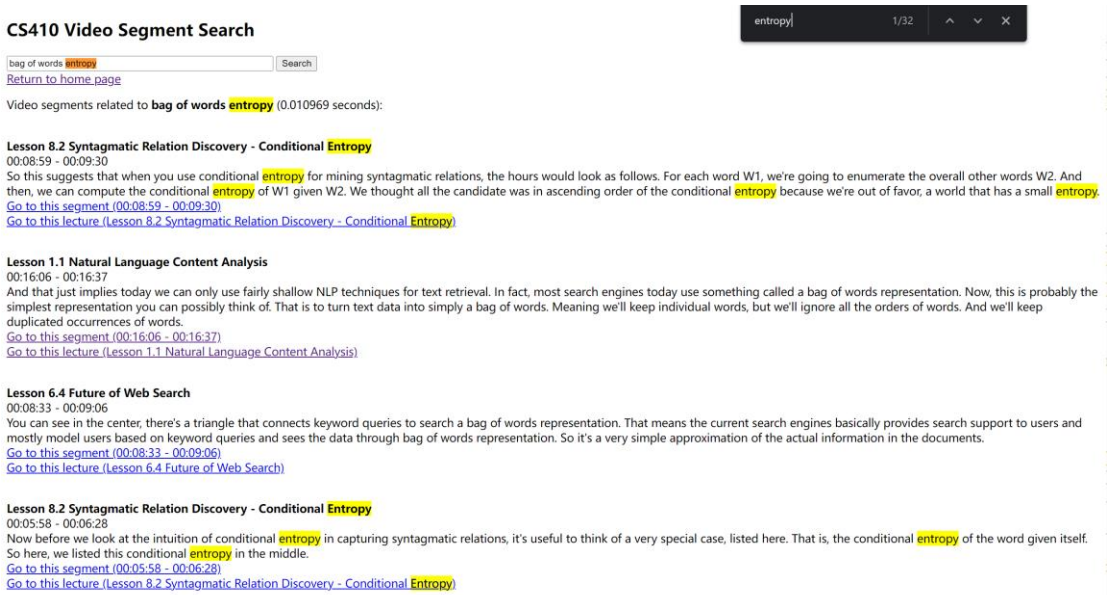
(b)

Figure 7 (a) Search result for query "Rocchio"; (b) Lecture video in Coursera after clicking link to second video segment

As mentioned in Section 2, the search engine in Coursera can only return the video segments whose transcript contains all the query terms. For example, the search engine returns no result if the query is "bag of words entropy", since no segment contains all these terms at the same time. The same query is tested on the search engine application developed in this project. As shown in Figure 8, the developed search engine can return the video segments whose transcript contains "bag of word" or the segments whose transcript contains "entropy". This shows that the developed search engine is capable to return the result for queries whose terms are not closed related to each other.



(a)



(b)

Figure 8 (a) Search result for query "bag of words entropy" with highlight of "bag of words"; (b) Search result for query "bag of words entropy" with highlight of "entropy".

6 Performance Evaluation

To further evaluate the performance of the developed search engine application, a set of queries is selected and used as the test cases to test the application. For each of the selected queries, the relevance of the top 10 returned video segments is manually judged, and the precision@10 is calculated. The recall of the test cases is not evaluated, since the evaluation of recall needs the manual relevance judgement of all the segments in the collection (2188 segments) against the queries. The queries, precision@10, and average precision are listed in Table 1.

Table 1 Precision of Set of Queries

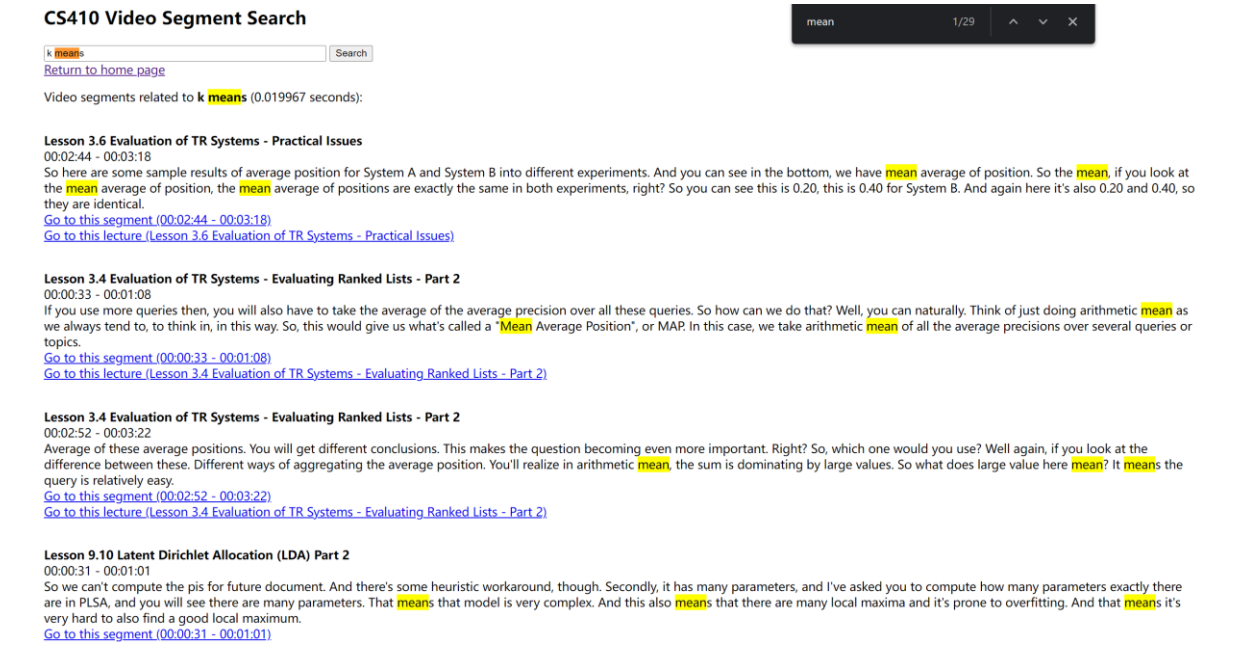
Query	Precision@10
semantic analysis	0.9
syntactic analysis	0.9
ambiguity	0.9
pos tagging	0.7
bag of words	1
pull mode	0.8
push mode	0.8
search engine	1
recommender system	1
bm25	1
ranking function	1
Vector space model	1
IDF Weighting	1
TF transformation	0.7
Inverted index	1
Precision	0.9
Recall	1

Query	Precision@10
Average precision	0.8
Query Likelihood	1
Unigram Language Model	1
Smoothing	1
Rocchio Feedback	1
KL Divergence	0.8
Map reduce	0.7
Page rank	0.8
Content based filtering	0.5
Threshold Learning	1
Collaborative Filtering	1
Paradigmatic relation	1
Syntagmatic relation	1
Conditional entropy	1
Mutual information	1
Maximum likelihood	1
Posterior probability	1
Topic model	0.7
Background model	1
Mixture model	1
EM algorithm	1
PLSA	1
LDA	1
Text clustering	1
K Means	0
Naïve bayes	1
Logistic regression	1
Opinion mining	1
Sentiment classification	0.8
Causal Topic Modeling	1
Average Mean	0.9085

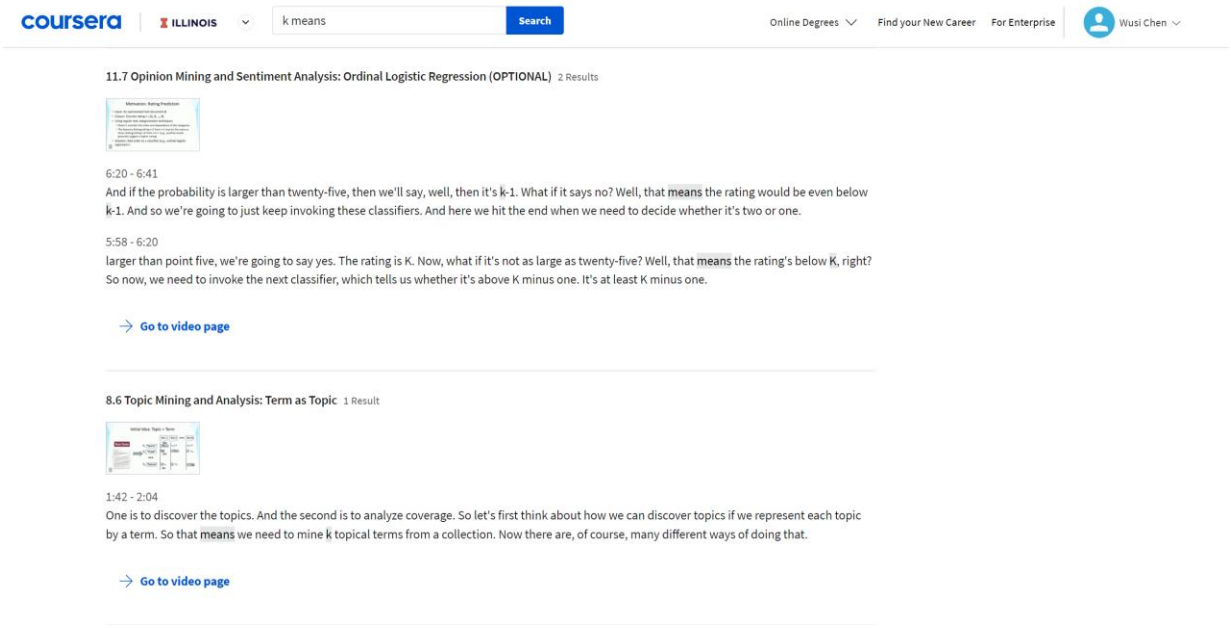
As shown in Table 1, the developed search engine application can effectively return the relevant video segments in the top 10 returned segments. However, the precision is 0 when the query is “K means”, which means the none of the top 10 returned video segments returned is related to the concept of “K means”. The screenshot of the partial result is shown in Figure 9 (a). As shown in Figure 9 (a), this issue is because the word “mean” has the following word-level ambiguity:

- The word “mean” can be a noun (average in math).
- The word “mean” can be a verb (explaining or clarifying a term or a sentence).

The query “k mean” is also run on the search engine in Coursera. The result screenshot is shown in Figure 9 (b). Similarly, none of the returned video segments is related to the concept “k mean”. The issue is suggested be resolved by using 2-gram of word when running Metapy python library.



(a)



(b)

Figure 9 (a) Result of "k mean" from developed search engine. (b) Result of "k mean" from search engine in Coursera.

Appendix

(a) **(b)**

Figure 10 (a) Flowchart for parser (parser.py); (b) Flowchart for "search" callback function (in bottle_app.py)