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Individual Project

1. Abstract

The primary objective of this project is to develop a comprehensive search engine system, encompassing a Scrapy-based web crawler, a Sci-kit-learn-powered indexer, and a Flask-based query processor. These components are designed to demonstrate and apply the wide range of skills acquired this semester, which include aspects of web scraping, data indexing, and query processing within a web application framework. The implementation of the project was successful, fulfilling all the aforementioned requirements.

Given additional time, the next phase of development would focus on enhancing the efficiency and breadth of the web crawler through the introduction of concurrent and distributed crawling. This advancement would significantly reduce the time required for web scraping, thus enabling the acquisition of a larger corpus of documents for indexing and searching. Furthermore, to increase the user experience and accessibility of the search engine, the introduction of a graphical user interface (GUI) would be a priority. This dual-interface approach of having a GUI and a command line interface (CLI) aims to cater to a wider audience, accommodating both technical users and those who prefer a more intuitive graphical interaction.

2. Overview

Solution outline

The assignment calls for the creation of three main components: a web crawler, an inverted index data structure, and a query processor. With that said, my solution covers all these parts.

The web crawler will navigate to various pages of the TMZ news website. Specifically, it will look at the news, sports, and hip-hop sections; and it will keep navigating to the next page, if one is available, until it reaches either its page limit or depth limit. Each page contains an article, so the crawler is then tasked with iterating over each part of the articles and combining them into a single document. Each document then gets added to a csv file containing all the documents' texts along with their corresponding titles.

The inverted index is a python dictionary where the key is every word that has appeared in the corpus of documents that was just scraped and stored in the csv file. The values are postings list that contains tuple pairs of numbers. The first number in the tuples is the document ID of each document that the word was found in. For our purposes, each document's ID is just the index of its position in the csv file. The second number in the tuples is the TF-IDF score for each word-document pair. These scores are necessary to perform the Top-K ranking of the documents later.

The processor, broadly speaking, will consist of a front-end and back-end component. The front end is a simple application that the user can download and run locally on their machine. The back end consists of several scripts running on an Ubuntu server that's being hosted on AWS.

Relevant Literature

Key resources that I referenced throughout the development process include the TMZ news website and a tutorial by freeCodeCamp.org on how to use and set up Scrapy for web crawling and scraping. I inspected the TMZ pages to see how their HTML was structured. This allowed me to set rules for the web scraper, such as which tags to look for in the article and where to look to navigate to the next page. The Scrapy tutorial showed me how to set up a Scrapy project from scratch and what basic functions to use to navigate through the different tags on a webpage.

3. Design

System Capabilities

The system is capable of performing three main functions. The first is crawling the various TMZ pages, scraping the contents of these pages, and storing the resulting documents in a csv file. The second is creating the inverted index, converting the index into a pickle file, and creating a document-term matrix from the index. The third is accepting user queries and processing them so that they return the top-10 matching documents.

Aside from these main capabilities that the user can interact with, there are also internal functions that the system uses in a few different intermediate steps. The first of these is cleaning the documents and their titles after they are scraped. When the articles are sent to the csv file, they get stored in a very messy format, so it is the job of the *doc_cleaner* program to clean them up from there. The cleaning consists of stripping away any extra lines or spaces that shouldn't be there and removing any duplicate articles. The duplicates are the result of the main TMZ homepage containing some articles from other subsections of the site. When the crawler scrapes the main news page and then subsequently scrapes the hip hop and sports pages, it may have navigated to some articles that it has already been to.

The system also handles query validation in the form of spelling correction. When a user inputs a query, the system cleans and normalizes it like it does for any other document in the corpus, but it also corrects any misspelled words or words that did not appear in the corpus. In terms of error checking, the system is capable of raising and catching various exceptions. These include a user trying to run a query before the index is built and trying to build the index before the sites have been scraped, among others. In both cases, exceptions are thrown by the system and are then caught by the application script so that the user can receive a helpful error message instead of the error itself.

Interactions

There are two main interactions in the system, those being the user's interactions with the command line interface and the front-end script interacting with the server on AWS. The user interacts with the application by entering one of the available commands to the command line. With the command now received from the user, the application then sends an API call to the server requesting the appropriate function. The server executes the desired function and sends back any necessary data to the application. Finally, when the application receives the data, it outputs to the shell for the user to see.

Integration

As mentioned before, the front-end and back-end components exist separately, but are integrated together through the use of the Ubuntu session on the AWS server. The front-end makes API calls to the back-end, allowing it to use all of the functionality that is on the server without having it do the computing locally on the user's machine. This integration applies more to how the user interacts with the system, however, for the sake of development and version control, the two components are also integrated on GitHub in this project's repository.

4. Architecture

Software Components

<u>Front End</u>

The user interaction lies in the front-end, which consists of a single Python script: *application.py*. This module is the primary interface for user interactions and communication with the server. Exception handling is another important feature, catching and resolving errors before they reach the user.

<u>Back End</u>

Web Crawler:

- Located within its specific project folder, the web crawler houses all the elements of a basic Scrapy project, most of which are initialized upon project creation. The main files to consider are as follows:
  - Items File: Defines the *ArticleItem* class with the fields *title* and *text*. This provides structure for data scraped from the websites.
  - Article Spider Program: Implements a specific spider for crawling the TMZ pages. It outlines parsing rules, including allowed domains, start URLs, and navigation strategies for site exploration.
- The result of the web crawler's operation is the creation of the *docs.csv* file. Users are encouraged to re-initiate the crawl process for up-to-date information.

Document Cleaner:

- Following data collection, the *doc_cleaner.py* program cleans each document by stripping it of extra spaces and new lines.
- Following the document cleaning step is the document normalization step, which comes in the form of the *normalize_text* function. Cleaning the text, removing emojis, lowercasing, removing stop words, and lemmatization are steps in the normalization process.
- Additionally, a spelling correction function helps with query matching by adjusting misspelled words based on edit distance calculations against each document in the corpus.

Indexer:

- The indexing step is handled by *indexer.py*, which is dedicated to transforming cleaned data into the TF-IDF inverted index.
- The index is serialized into a pickle file for efficient storage and retrieval. The indexer provides mechanisms to both create the pickled index file and restore the original index data structure from the pickle file.

Processor:

- The *processor.py* script processes all the user defined queries. It includes a large set of helper functions which are all used to create the *process_query* function, which manages the comparison of user queries against the document-term matrix. Dot product and cosine similarity measurements ensure relevant and accurate search results.

Flask Application:

- In addition to the core components, the Flask-based *app.py* file serves as the integration layer, knitting together the functionalities of the document cleaner, indexer, and processor. It interprets server requests, directing them to the appropriate module while managing the Flask application's routing and API interactions.

Interfaces

The user interface is a Command Line Interface (CLI) which immediately asks the user for input. The prompt displays the set of available commands, and after the initial prompt, users can enter commands directly into the CLI. Each command corresponds to a specific function, such as scraping the webpages, building the index, querying the corpus, and exiting the application. Users are free to execute commands in perpetuity until they stop the program.

Implementation

In the implementation phase, we translate our design concepts into functional code. This section describes all the software and technical underpinnings employed to implement the project.

Inverted Index:

- We use the inverted index to quickly retrieve relevant documents.
- It is implemented as a Python dictionary, mapping each key term from the document corpus to a postings list. The postings list consists of tuples, with each tuple containing two elements: the document ID where the term appears and the term's TF-IDF score for that specific document.

Document-Term Matrix:

- We also constructed a document-term matrix to support complex query processing. This matrix is represented as a 2D Python list, where each row corresponds to a document in the corpus, and each column represents a term from the corpus, arranged in sorted alphabetical order.
- The value at any given position in the matrix signifies the TF-IDF score of the term in that document.
- The matrix is used to compute the dot product of user queries against all the document vectors in the corpus.

Storage Solutions:

- To ensure the persistence and accessibility of the search engine's core data structures, we employed specific storage solutions tailored to the needs of the components:
- The inverted index is serialized and stored in a pickle file. This approach allows for the index to be efficiently loaded into memory when the query processor is initiated, ensuring quick access to the indexed data for query processing.
- The original documents from which the index is constructed are stored in a csv file. This format was chosen for its simplicity and ease of access, allowing the indexer to efficiently process and index new documents once they are scraped.

5. Operation

Installation

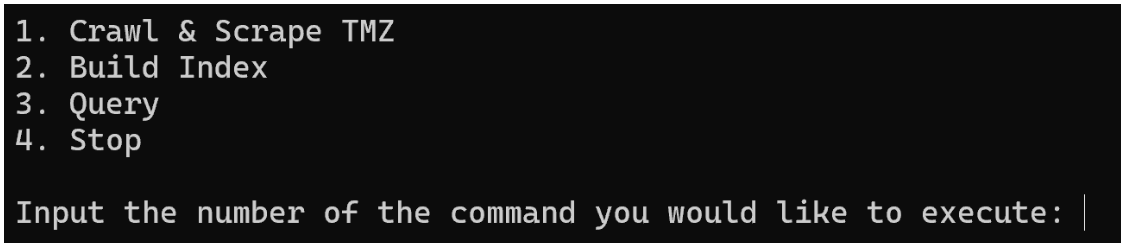
1. Navigate to this project repository at: https://github.com/alekpop2/News_Crawler_and_Retriever/tree/main
2. Download the file: *application.py*
3. On your machine, navigate to the directory that *application.py* is in.
4. Open your command prompt for that directory.

Software Commands

1. Complete the installation steps above.
2. On your command prompt, type the command: *python application.py*

Inputs

1. Complete the software command steps above.
2. The program should produce an output like the following in your command prompt:



```
1. Crawl & Scrape TMZ
2. Build Index
3. Query
4. Stop

Input the number of the command you would like to execute:
```

3. From there, enter the number associated with one of the available commands (1-4). It is recommended that the user run commands (1-3) in order the first time they run the program to get the most up-to-date documents and index.

6. **Conclusion**

Results

In assessing the outcomes of the project, it is essential to recognize that the primary aim was not to advance research or uncover novel findings. Instead, the project sought to demonstrate proficiency in executing key components: web crawling, indexing, and query processing, all while integrating these elements into a system hosted via a Flask application. By these measures, the project has achieved notable success, fulfilling its objectives and demonstrating the practical application of these technologies. Additionally, the project's attention to detail in handling the finer aspects of each component—such as spelling correction and exception handling—further highlights its success.

Outputs

Here, we detail the responses and feedback provided by our system through its Command Line Interface (CLI) upon execution of various commands. The outputs associated with the four main commands available to the user—scrape website, build index, query, and exit—are below.

- Upon selecting the scrape website command, the system initiates the web crawling process. The output is either a success message or an exception message.
- The build index command triggers the process of creating an inverted index from the scraped website data. The output is either a success message or a message saying that the webpages have not been scraped yet.
- The query command is central to the search engine's functionality, allowing users to input text queries and receive the top-10 matching documents in return. The output is either the top-10 documents or a message saying that the inverted index has not been created yet.
- Finally, the exit command provides the simple function of terminating the command loop and concluding the user's session with the search engine. The output for this command is a "Goodbye," signaling the end of the session.

Caveats/Cautions

While using the project, users should be aware of two primary caveats that could impact their experience and the relevance of search results. Understanding these limitations is crucial for optimizing the use of the search engine.

The first caveat involves the potential use of an outdated *docs.csv* file. If users initiate query operations without first executing the scrape command, there is a significant likelihood that the search will return documents that are not reflective of the most current information available. This scenario primarily arises if the scrape and index commands are not run at the beginning of each session. To mitigate this issue, users are strongly advised to always perform a fresh scrape and indexing at the start of their interaction with the program. While this requirement may seem like a limitation, it also presents an exciting feature of the project. Given that the TMZ news site is updated daily, executing the web crawler regularly ensures access to the latest articles. This means that with each crawl, especially when conducted at longer intervals, users can access and index a fresh batch of content, keeping outputs dynamic and current.

The second caveat relates to the thematic scope of the search queries. The search engine's document corpus is sourced from TMZ, a news outlet predominantly focused on celebrity gossip, sports, and hip-hop music. Consequently, queries related to these topics are likely to yield relevant results. However, users should limit their expectations for queries outside of these areas, such as those concerning general news, politics, or technical subjects. This limitation is not indicative of a flaw within the project's design or implementation but rather a reflection of the chosen document source's thematic focus. Nevertheless, as long as the search engine is returning the top 10 documents for a given query, users can be assured that it is working properly. This consideration underscores the importance of aligning query topics with the content themes of the indexed documents to maximize the relevance and utility of search results.

7. Data Sources

TMZ Pages:

- News: https://www.tmz.com/
- Sports: https://www.tmz.com/sports/
- Hip-Hop: https://www.tmz.com/hip-hop/

8. Test Cases

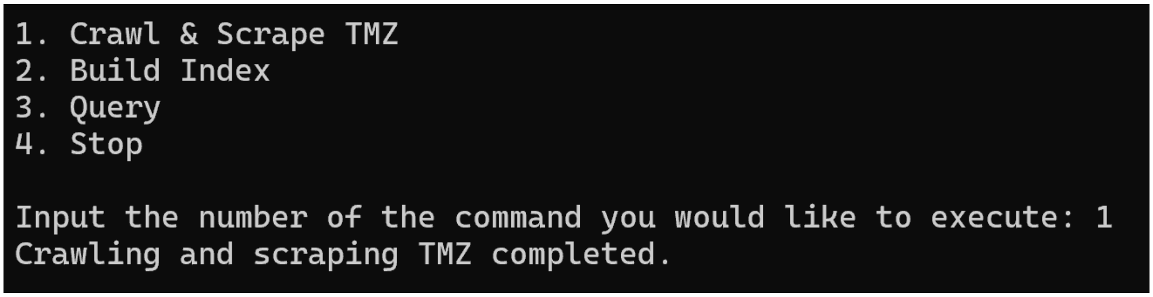
Framework: N/A

Harness: N/A

Coverage

Below is a list of the available commands and what a successful execution of each one should look like.

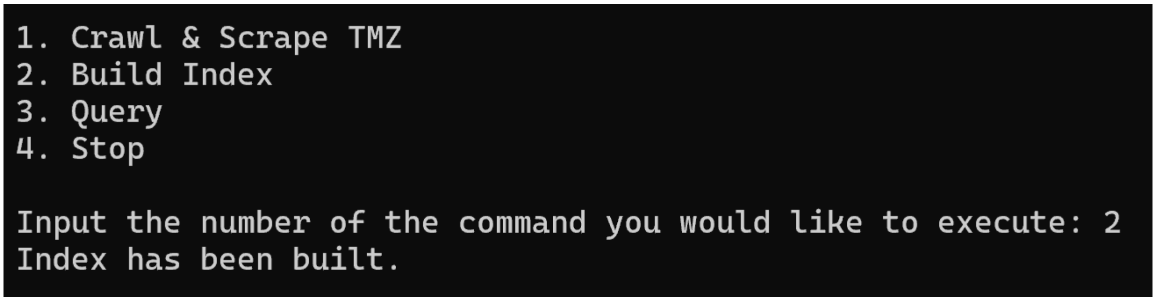
1. Crawl & Scrape TMZ



```
1. Crawl & Scrape TMZ
2. Build Index
3. Query
4. Stop

Input the number of the command you would like to execute: 1
Crawling and scraping TMZ completed.
```

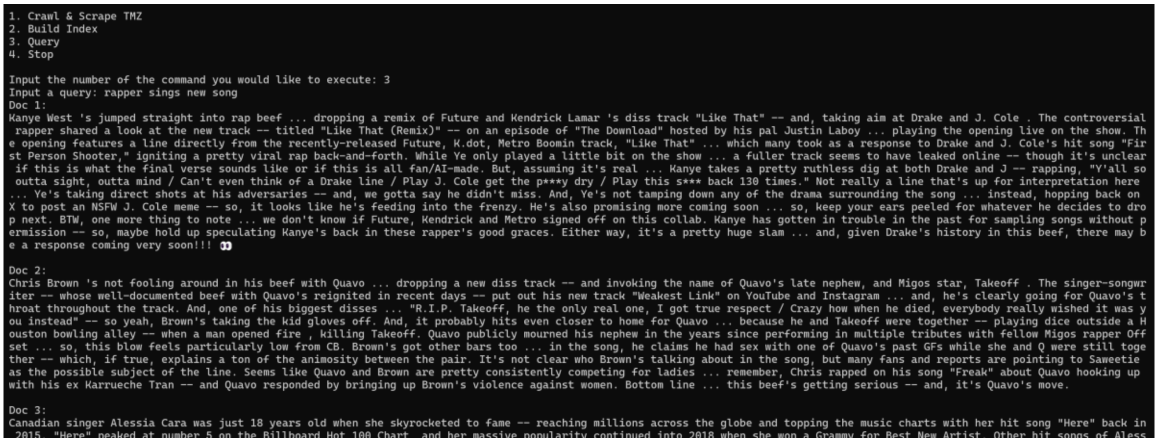
2. Build Index



```
1. Crawl & Scrape TMZ
2. Build Index
3. Query
4. Stop

Input the number of the command you would like to execute: 2
Index has been built.
```

3. Query



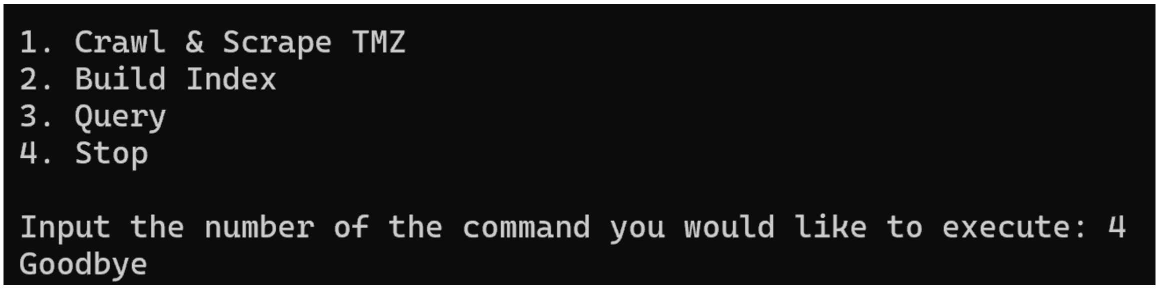
```
1. Crawl & Scrape TMZ
2. Build Index
3. Query
4. Stop

Input the number of the command you would like to execute: 3
Input a query: rapper sings new song
Doc 1:
Kanye West 's jumped straight into rap beef ... dropping a remix of Future and Kendrick Lamar 's diss track "Like That" -- and, taking aim at Drake and J. Cole . The controversial
 rapper shared a look at the new track -- titled "Like That (Remix)" -- on an episode of "The Download" hosted by his pal Justin Laboy ... playing the opening live on the show. Th
e opening features a line directly from the recently-released Future, K.dot, Metro Boomin track, "Like That" ... which many took as a response to Drake and J. Cole's hit song "Fir
st Person Shooter," igniting a pretty viral rap back-and-forth. While Ye only played a little bit on the show ... a fuller track seems to have leaked online -- though it's unclear
 if this is what the final verse sounds like or if this is all fan/AI-made. But, assuming it's real ... Kanye takes a pretty ruthless dig at both Drake and J -- rapping, "Y'all so
 outta sight, outta mind / Can't even think of a Drake line / Play J. Cole get the p***y dry / Play this s*** back 130 times." Not really a line that's up for interpretation here
... Ye's taking direct shots at his adversaries -- and, we gotta say he didn't miss. And, Ye's not tamping down any of the drama surrounding the song ... instead, hopping back on
X to post an NSFW J. Cole meme -- so, it looks like he's feeding into the frenzy. He's also promising more coming soon ... so, keep your ears peeled for whatever he decides to dro
p next. BTW, one more thing to note ... we don't know if Future, Kendrick and Metro signed off on this collab. Kanye has gotten in trouble in the past for sampling songs without p
ermission -- so, maybe hold up speculating Kanye's back in these rapper's good graces. Either way, it's a pretty huge slam ... and, given Drake's history in this beef, there may b
e a response coming very soon!!! 👀

Doc 2:
Chris Brown 's not fooling around in his beef with Quavo ... dropping a new diss track -- and invoking the name of Quavo's late nephew, and Migos star, Takeoff . The singer-songwr
iter -- whose well-documented beef with Quavo's reignited in recent days -- put out his new track "Weakest Link" on YouTube and Instagram ... and, he's clearly going for Quavo's t
hroat throughout the track. And, one of his biggest disses ... "R.I.P. Takeoff, he the only real one, I got true respect / Crazy how when he died, everybody really wished it was y
ou instead" -- so yeah, Brown's taking the kid gloves off. And, it probably hits even closer to home for Quavo ... because he and Takeoff were together -- playing dice outside a H
ouston bowling alley -- when a man opened fire , killing Takeoff. Quavo publicly mourned his nephew in the years since performing in multiple tributes with fellow Migos rapper Off
set ... so, this blow feels particularly low from CB. Brown's got other bars too ... in the song, he claims he had sex with one of Quavo's past GFs while she and Q were still toge
ther -- which, if true, explains a ton of the animosity between the pair. It's not clear who Brown's talking about in the song, but many fans and reports are pointing to Saweetie
as the possible subject of the line. Seems like Quavo and Brown are pretty consistently competing for ladies ... remember, Chris rapped on his song "Freak" about Quavo hooking up
with his ex Karrueche Tran -- and Quavo responded by bringing up Brown's violence against women. Bottom line ... this beef's getting serious -- and, it's Quavo's move.

Doc 3:
Canadian singer Alessia Cara was just 18 years old when she skyrocketed to fame -- reaching millions across the globe and topping the music charts with her hit song "Here" back in
 2015. "Here" peaked at number 5 on the Billboard Hot 100 Chart, and her massive popularity continued into 2018 when she won a Grammy for Best New Artist. Other hit songs of Aless
```

4. Stop



```
1. Crawl & Scrape TMZ
2. Build Index
3. Query
4. Stop

Input the number of the command you would like to execute: 4
Goodbye
```

9. Source Code

Listings

https://github.com/alekpop2/News_Crawler_and_Retriever/tree/main

Dependencies

Python Libraries:

Bisect	Flask	Math	NLTK
NumPy	OS	Pandas	Pickle
RE	Sci-Kit-Learn	Scrapy	Subprocess

Documentation

Bisect: https://docs.python.org/3/library/bisect.html
Flask: https://flask.palletsprojects.com/en/3.0.x/
Math: https://docs.python.org/3/library/math.html
NLTK: https://www.nltk.org/
NumPy: https://numpy.org/doc/
OS: https://docs.python.org/3/library/os.html
Pandas: https://pandas.pydata.org/docs/
Pickle: https://docs.python.org/3/library/pickle.html
RE: https://docs.python.org/3/library/re.html
Sci-Kit-Learn: https://scikit-learn.org/stable/
Scrapy: https://docs.scrapy.org/en/latest/
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