Search Engine (Prácticas 1-7)

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Sistemas de Recuperación de Información

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Introduction

This document is part of the Search Engine project for the Sistemas de Recuperación de Información course at the University of Jaén in Spain. Contained within it is valuable information and explanations concerning the design decisions, implementation and general development of the project.

The development of this project was divided into 7 distinct parts, representing practices one through seven. The first three parts were directly related to the preprocessing of the input documents (html filtration, normalization, tokenization, stop word removal and stemming), while the fourth and fifth were dedicated to index building and other necessary structures. The last two were devoted to query processing and searching the index to get the wanted results.

This project was developed in the Spyder (Anaconda3) IDE using the Python programming language (version 3.7.4). The necessary packages to use the search engine are:

- nltk 3.4.5
- psutil 5.6.3
- beautifulsoup4 4.8.0

Diagrams

- ## Main diagram

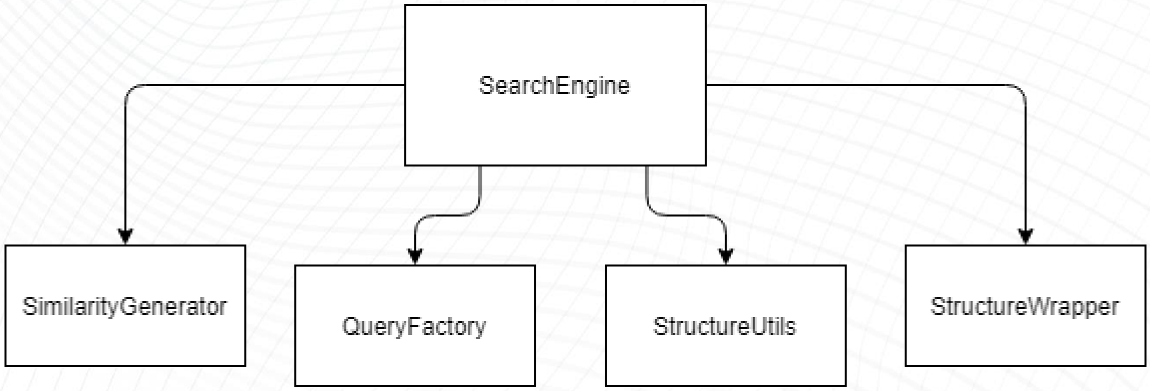


Figure 1.0 – Relations between the main classes of the project

- ## Preprocessing (Practices 1-3)

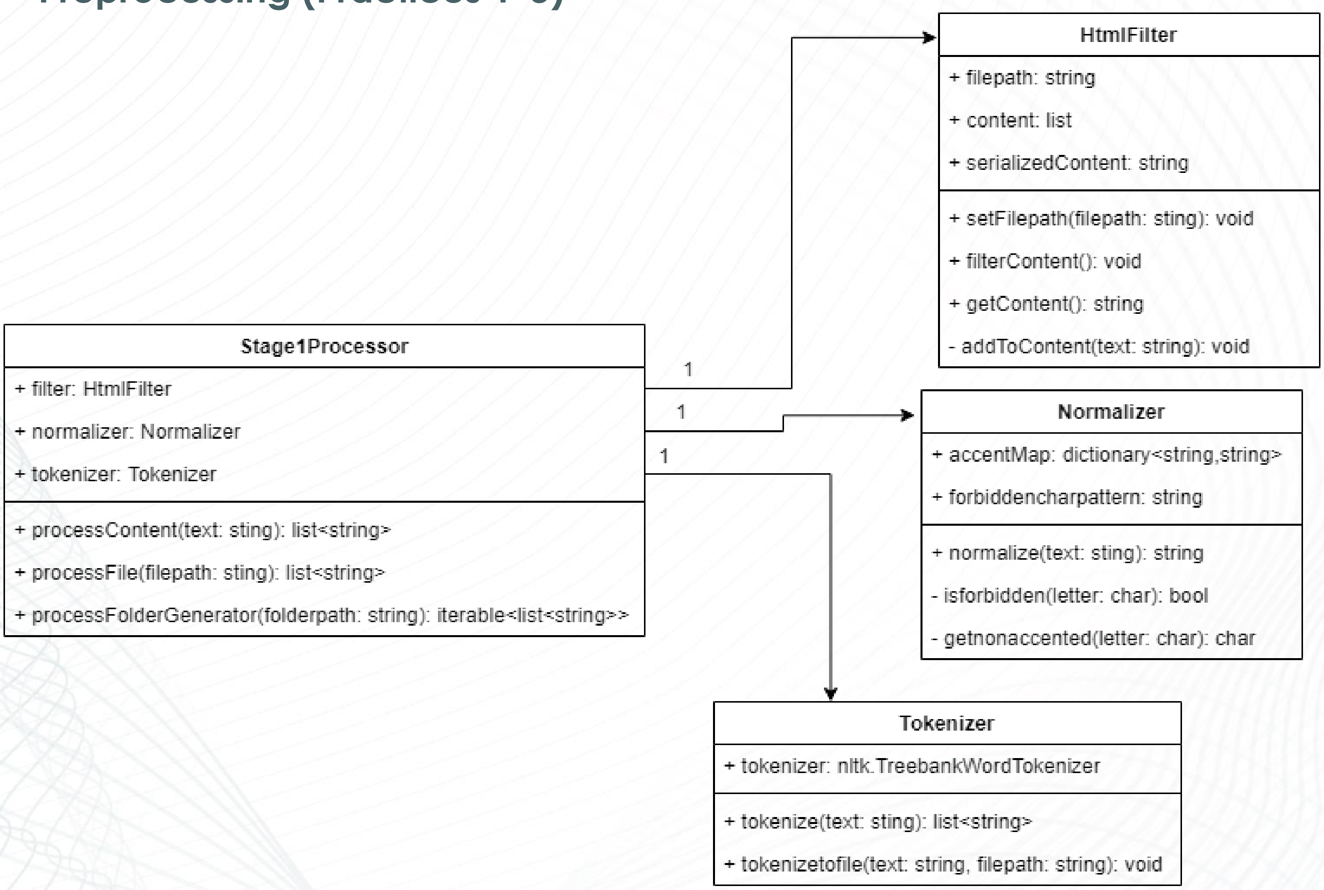


Figure 1.1 – Stage 1 preprocessing (text to words)

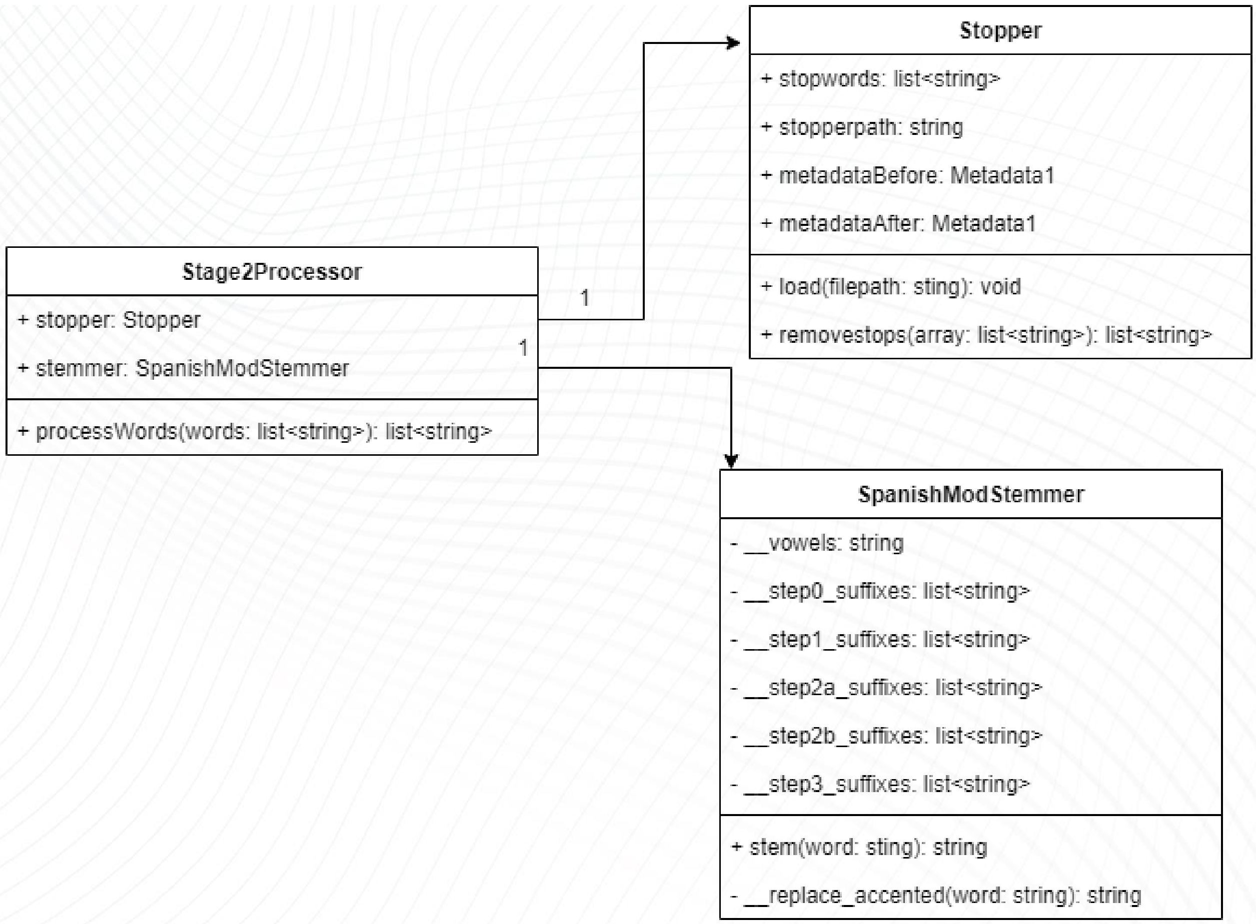


Figure 1.2 – Stage 2 preprocessing (word transformation)

- **Structures (index, word references and file references) (Practices 4 and 5)**

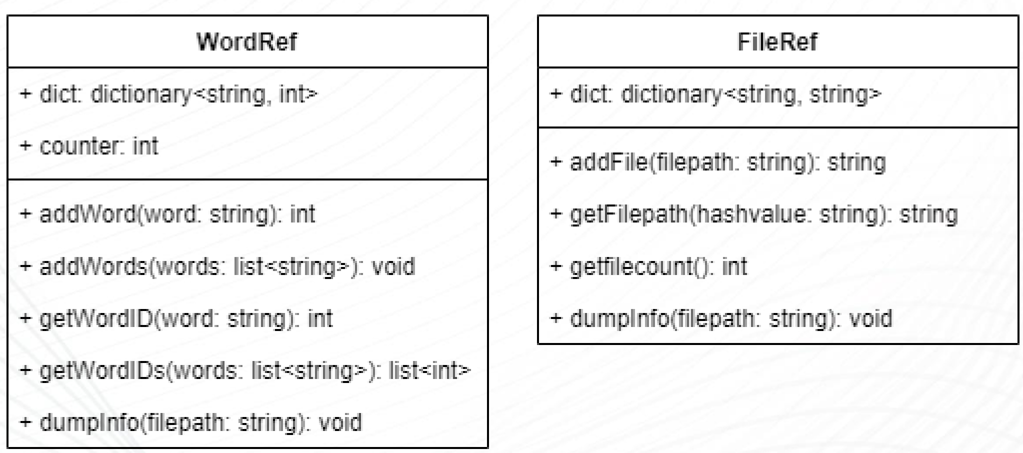


Figure 1.3 – Structures containing references

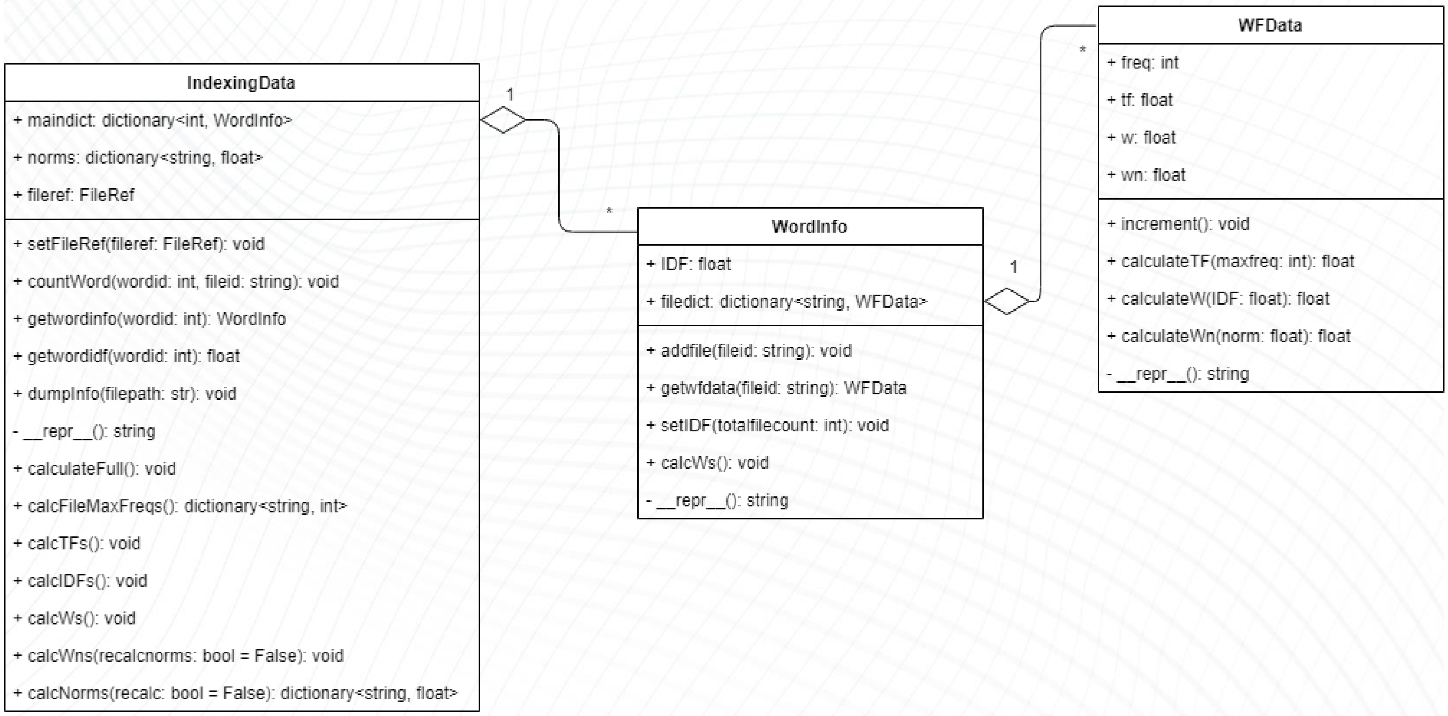


Figure 1.4 – Index structure(s)

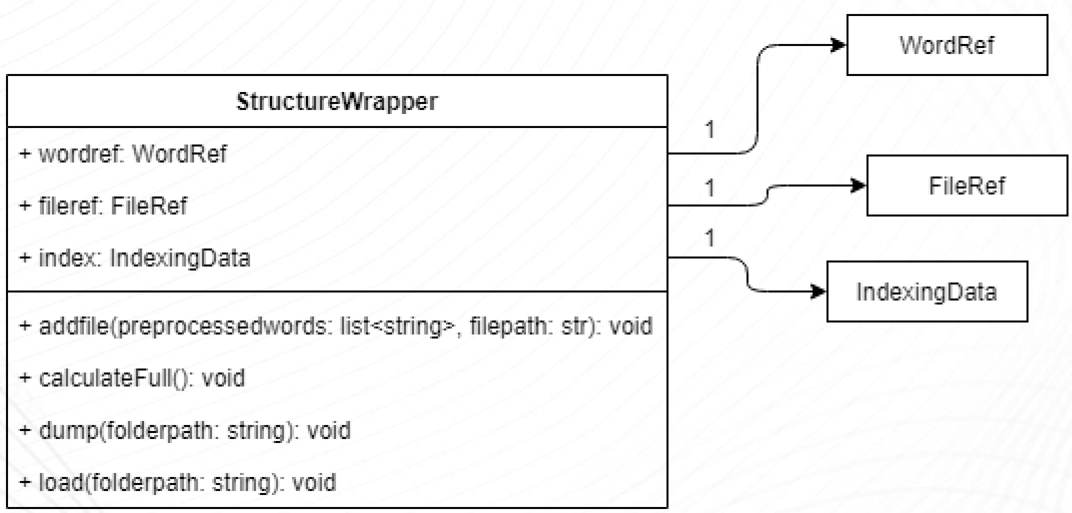


Figure 1.5 – Structure wrapper (use to handle lifetime grouping and loading/saving)

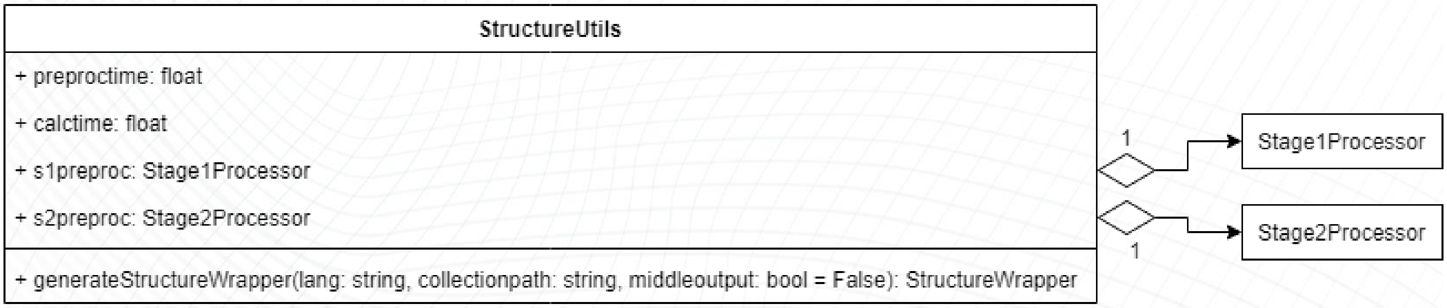


Figure 1.6 – Structure utility class (used to process all collection files and creates a StructureWrapper, along with all the structures contained within it)

- ## Query handling (Practices 6 and 7)

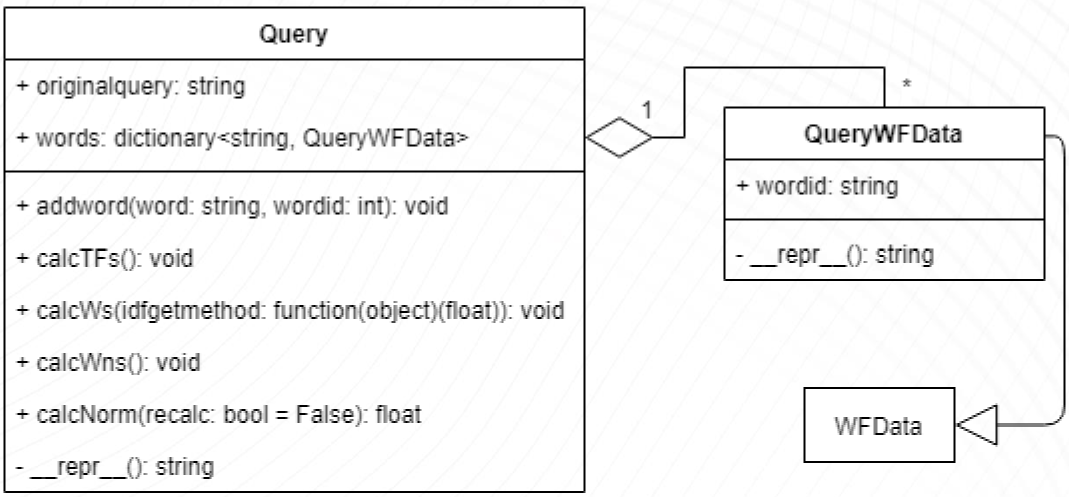


Figure 1.7 – Objects of these classes encapsulate all data needed before, during and after the processing of the input queries

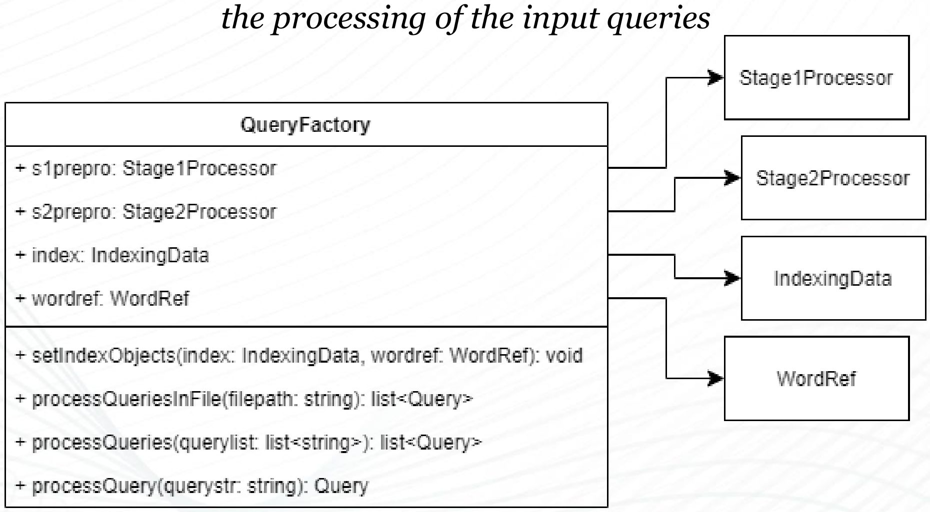


Figure 1.8 – This class is used to process input queries and create Query objects

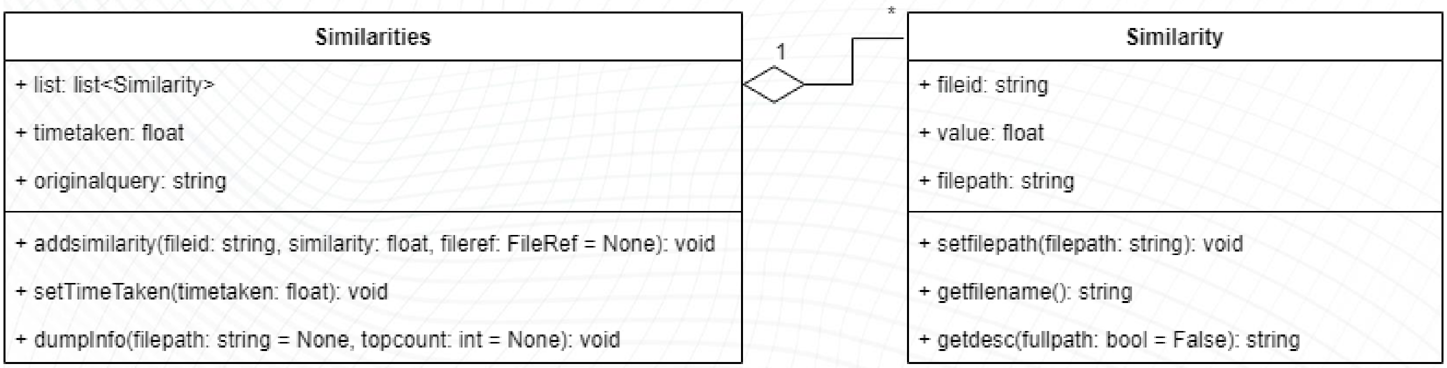


Figure 1.9 – Objects of these classes encapsulate result data from query search

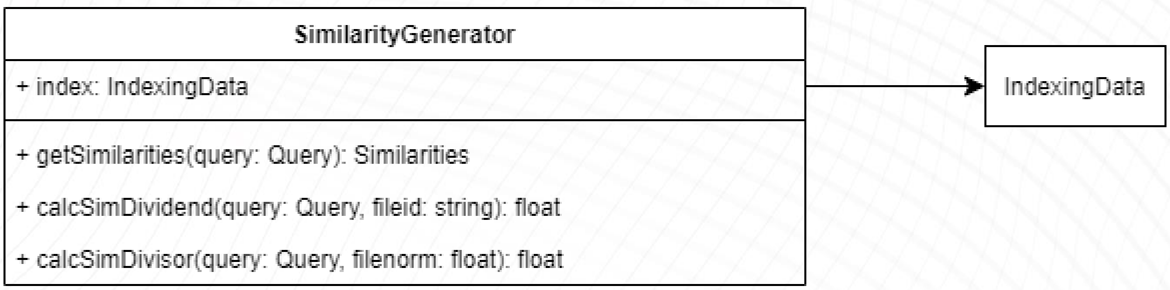


Figure 1.10 – This class is used to execute query search on a specified index and generate matching similarities

- ## Search engine (Practice 7)

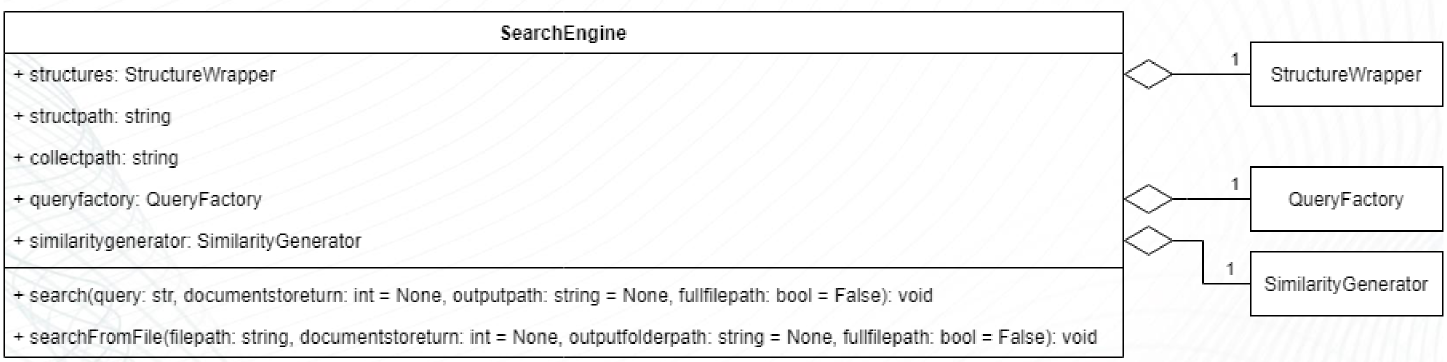


Figure 1.11 – Main class

Structure design

• WordRef – word/token dictionary

This structure is a simple dictionary, where the key is a string, and the value is an integer. The key is the word itself and the value is an ID by which we identify this word in all the other structures. The ID value is calculated as a simple auto-increment counter, located in the class.

We add words to this structure when they appear for the first time in one of the files from which we create the index. Because of this, all the words that are in this structure, appear in the index at least once. We use this to determine which words in an input query are relevant to the index and to find out their IDs.

• FileRef – file dictionary

This structure is a dictionary, where both the key and the value are strings. The value is the full path to the file that we are adding, and the key is its hash value. The key is an ID by which we identify this file in the other structures. The hash value is calculated with the integrated Python `hash(str)`method.

We use this structure to find the full paths to the files that are determined to be relevant to the input query.

• IndexingData – index

The most important structure, the index. This structure is organized as a dictionary of dictionaries. With the parent dictionary having the signature of <`wordid, WordInfo`>, and the child dictionaries having the signatures of <`fileid, WFData`>. During development, the main question was whether to have the parent dictionary be accessed by the `wordid`, or the `fileid`. In the end, I decided to organize the parent dictionary by words, as this would allow direct access during query processing, and would allow the best performance. The trade-off is that index creation takes a little longer, as it’s more difficult to calculate the maximum word frequencies per file and the norms used in normalized weight calculations.

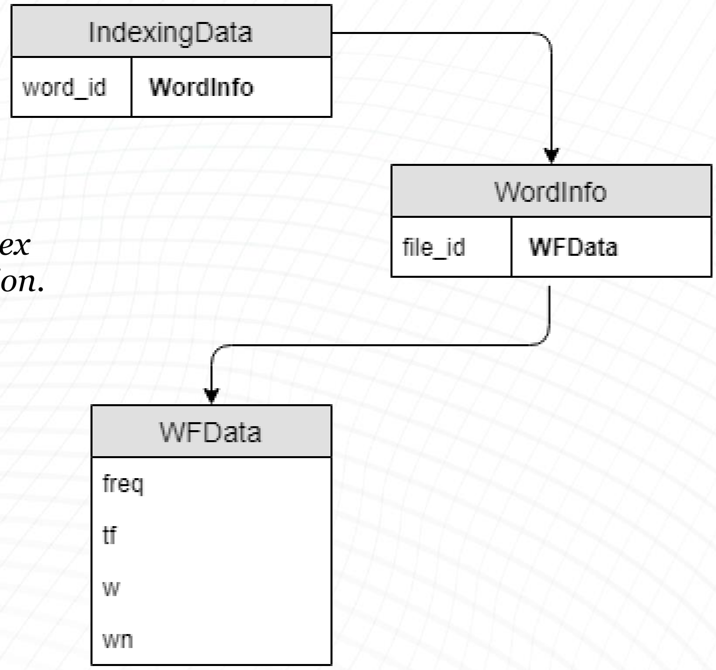


Figure 2.0 – Index dictionary organization.

Development

• Practice 1

To start of this practice, and the whole project, we had to implement a module to clean up .html files and get only relevant content from them. I decided to use the beautifulsoup4 package for this as it’s well documented and widely supported.

I combine the text content of the <title> tag and the <body> tag along with all its descendants that are a `NavigableString`, while skipping comments and scripts.

Next, we had to implement a normalizing module, to process the resulting content. I go through the text, only once, changing all letters to lowercase, replacing any accented letter with its non-accented counterpart (á -> a, etc.), and removing any forbidden characters.

Only the following characters are allowed:

```
[‘a’...’z’, ‘A’...’Z’, ‘ ‘, ‘_’, ‘-‘, ‘\n’,‘0’..’9’]
```

The rest are filtered out using a simple regular expression:

```
[^a-z0-9\s\_\-\n]
```

After that, we were to create a tokenizing module. During development, I used a regular expression for this, but for the sake of consistency, I switched to the `nltk` implementation of the `TreebankWordTokenizer`.

Modules mentioned in this description:

- Practice1/htmlfilter.py
- Practice2/normalization_tokenization.py

• Practice 2

For the second practice, we had to implement a module that would be used to remove stop words from the resulting token list. On this website, I found two .txt files containing Spanish stop words. I manually combined these two files into one file, contained in the Practice2 folder. During the initialization of the module, this file is loaded into a dictionary, and duplicate words are removed.

Modules mentioned in this description:

- Practice2/stopper.py

• Practice 3

Our main task for this practice was to create or find a capable stemming module. During testing, I tried using the `SnowballStemmer` implementation from the `nltk` package, but I ran into some problems. Since we already removed all the accents from the text, this implementation of the stemmer had problems properly stemming the input tokens. So, after some research, I found out that the `nltk` package uses the *Apache 2.0 license*, which allows modification of the source code. I downloaded the source code for the `SnowballStemmer` and modified it slightly so that it worked with non-accented text. After some testing and comparisons, I concluded that it was adequate for this project.

Modules mentioned in this description:

- Practice3/stemmer.py

• Practice 4

The development of the modules in this practice took the most time since I had to think of the design thoroughly. First, we had to create two straightforward structures, to hold references to the words and files that appear in the index structure. These two structures are explained adequately in the **Structures** part of this document.

For the index structure, we had to make something that would properly hold word-file pairs and the frequency data. I decided on creating an inverted index structure, as it would later allow easier access. The first dictionary in this structure is accessed by the word ID, referenced from the previously mentioned word reference structure. The dictionary values are also dictionary objects that are accessed by the file ID, and hold an integer as values, these integers represent the word frequency in that file.

Modules mentioned in this description:

- Practice4/references.py
- Practice4/indexing.py

- **Practice 5**

Now, we had to expand on the previously created index structure, and allow storage and calculation of more data, including normalized weights. The child dictionary was changed to hold an object of the class `WFData`, which encapsulates all needed data for that word-file pair. The child dictionary itself was also encapsulated into an object of the `WordInfo` class, along with data that was tied to the specific word, mainly ***IDFs***.

The class holding the parent dictionary was also expanded to contain some caching data (file norms), and to handle all the calculations. The most difficult calculations to implement were the ***tf*** calculations and the file norm calculations, as they required multiple passes through the whole structure. During early development, these calculations took significant time, as I approached them by first going through the whole file reference structure and gathering data for each file individually. Later, I changed the algorithm so that it goes through the index structure itself, and maps the data found in a local dictionary, that I later go through again to process it. The execution time reduced by a factor of 10, as I went from a complexity of:

$$O(num\_files * total\_word\_count)$$

To a complexity of:

$$O(average\_files\_per\_word * total\_word\_count)$$

I also created a class to hold all three structures during their lifetimes and handle their saving and loading from files. I used the `pickle` package to handle serialization.

Modules mentioned in this description:

- Practice5/indexing.py
- Practice5/structures.py
- Practice5/structures_serialization.py

- ## Practice 6

For practice 6 we had to decide how to handle query processing from text and then how to find similarities in the index.

I created a module that generates `Query` objects from input text queries. These objects are designed to hold all data relevant to the words in the query and are also designed as an inverted index, but in this case, we only have one file, the query itself.

I have also created a module that uses the index and the given `Query` object to find similarities. This module also calculates the necessary data needed for this process, including normalized weights. ***tf***s were calculated the same way as for the word-file pairs in the index. One problem here was how to handle words that do not appear in the index at all. ***IDF***s for these words were calculated like this:

$$idf_i = \log_2 \frac{total\_file\_count + 1}{1}$$

Considering that these words are not located in the word reference, there is no data for them in the index, and they are ignored in the similarity calculations. I used this formula for the similarity calculations:

$$sim(d_j, q) = \frac{\sum_{\forall_i \in q} wn_{ij} * wn_{iq}}{\sqrt{\sum_{\forall_i \in j} wn_{ij}^2} * \sqrt{\sum_{\forall_i \in q} wn_{iq}^2}}$$

I have also developed a module for config parsing, it looks for two distinct lines in the loaded .txt file:

- `structures=`*`path_to_folder_with_structures`*
- `collection=`*`path_to_collection_folder`*

Modules mentioned in this description:

- Practice6/queryhandling.py
- Practice7/similarity.py
- Practice6/config.py

• Practice 7

For this last practice, I was mostly just writing classes and modules to properly organize the previous modules, while also refactoring some things in the modules created earlier. I expanded the module dedicated to similarity generation, so that it has powerful output capabilities, to satisfy the output and formatting requirements for this practice.

I also developed a main class, called `SearchEngine`. This class is what wraps every developed module up into a usable form. It is loaded using a path to the config file and some optional arguments. It parses the config file using a module developed in the previous practice. If it finds a valid path to a structure folder, it tries loading the structures. If it manages to load the structures, it initializes other necessary modules for query processing and similarity generation and completes the initialization. If structure loading is unsuccessful, or a valid path to the structure folder is not found, it tries to generate new structures from the supplied collection path. If this is also unsuccessful, it terminates with an error.

After the class has loaded it can process queries using two methods, `search(query)` and `searchFromFile(filepath)`. Both methods take some optional arguments related to the output location, display formatting, and the number of sorted documents to return. The first method takes the query string, processes it and matches it against the index, outputting the results to a file or to the standard output. The second one takes a file path to a query file, which contains one query string per line. It handles each of these the same way as the first method.

The class also contains a method to save the structures to a specified folder, `save(folderpath)`.

Modules mentioned in this description:

- Practice7/similarity.py
- searchengine.py
- preprocessing.py
- structure_utils.py

Metadata

I developed a separate module to measure and contain metadata for some of these practices. The mentioned module is `metadata.py`. All metadata results are contained in the /metadata/ folder in the main package location.

- ## Practice 1 Metadata

```
Metadata1 (Practice1) stats:
    Files processed: 838
    Total collection tokens: 531736
    Average tokens per file: 634.5298329355609
    Time taken: 18.38745460016071
```

- ## Practice 2 Metadata

```
Metadata2 (Practice2 - before stop words removal) stats:
    Files processed: 838
    Total word count: 531736
    Average words per file: 634.5298329355609
    Minimum words in a file: 196
    Maximum words in a file: 1950
    Top 5 words by appearance:
        1. Word: de Count: 49758
        2. Word: la Count: 24982
        3. Word: el Count: 14685
        4. Word: en Count: 11892
        5. Word: y Count: 11781
    Time taken: 1.1713934000290465

Metadata2 (Practice2 - after stop words removal) stats:
    Files processed: 838
    Total word count: 306326
    Average words per file: 365.5441527446301
    Minimum words in a file: 156
    Maximum words in a file: 997
    Top 5 words by appearance:
        1. Word: jaen Count: 8423
        2. Word: diario Count: 5047
        3. Word: universidad Count: 4382
        4. Word: uja Count: 4052
        5. Word: 21 Count: 3437
    Time taken: 1.1713934000290465
```

• Practice 3 Metadata

```
Metadata2 (Practice3 - before stemming) stats:
    Files processed: 838
    Total word count: 306326
    Average words per file: 365.5441527446301
    Minimum words in a file: 156
    Maximum words in a file: 997
    Top 5 words by appearance:
        1. Word: jaen Count: 8423
        2. Word: diario Count: 5047
        3. Word: universidad Count: 4382
        4. Word: uja Count: 4052
        5. Word: 21 Count: 3437
    Time taken: 8.33084499996039

Metadata2 (Practice3 - after stemming) stats:
    Files processed: 838
    Total word count: 306326
    Average words per file: 365.5441527446301
    Minimum words in a file: 156
    Maximum words in a file: 997
    Top 5 words by appearance:
        1. Word: jaen Count: 8423
        2. Word: univers Count: 5866
        3. Word: diar Count: 5062
        4. Word: sit Count: 4195
        5. Word: uja Count: 4052
    Time taken: 8.33084499996039
```

• Practice 4 Metadata

```
Time taken: 0.7454186996474164
Structure info:
Type: <class 'Practice4.indexing.IndexingData'> Size: 11754432 b
System: Windows-10-10.0.18362-SP0
Processor: AMD64 Family 23 Model 24 Stepping 1, AuthenticAMD
Ram: 14 GB
```

• Practice 5 Metadata

```
Time taken: 0.6964298999992025
Structure info:
Type: <class 'Practice5.indexing.IndexingData'> Size: 55099498 b
System: Windows-10-10.0.18362-SP0
Processor: AMD64 Family 23 Model 24 Stepping 1, AuthenticAMD
Ram: 14 GB
```

• Practice 6 and 7 Metadata

The results of query processing itself are the metadata for these two practices and can be found in the *query_file_folder*/Query Results/ folder after `searchengine.py` execution.

Application parameters

The main entry point for the application is the `searchengine.py` script. The script takes three command line arguments:

1. `full file path to the config file`
2. `full file path to the query file`
3. `count of documents to return`

These arguments are used to instantiate and configure an object of the class `SearchEngine`. Some additional parameters of the class are whether to generate middle files during preprocessing, which contain results from each stage of preprocessing and are stored in *collectionfolder*/middle_output/, and whether to display processing time. Both are set to `True` in this script.

After the search engine is instantiated, the file located at the path supplied by the second argument is processed and its results are saved to files, located at *query_file_folder*/Query Results/.

After this is completed, the structures in the engine are saved to the specified structures folder path in the config file. If no folder path for structures is specified, this step is skipped, and the application terminates.

There are several other scripts included in the project (main1to30.py, main4.py, main5.py, main6.py). They were used during development and are there to display individual testing of the modules.

Application execution

The following are screenshots of the application and its environment:

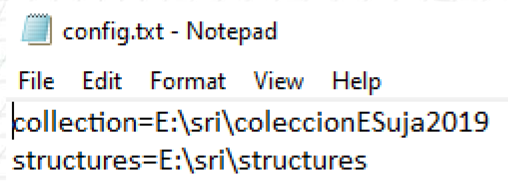
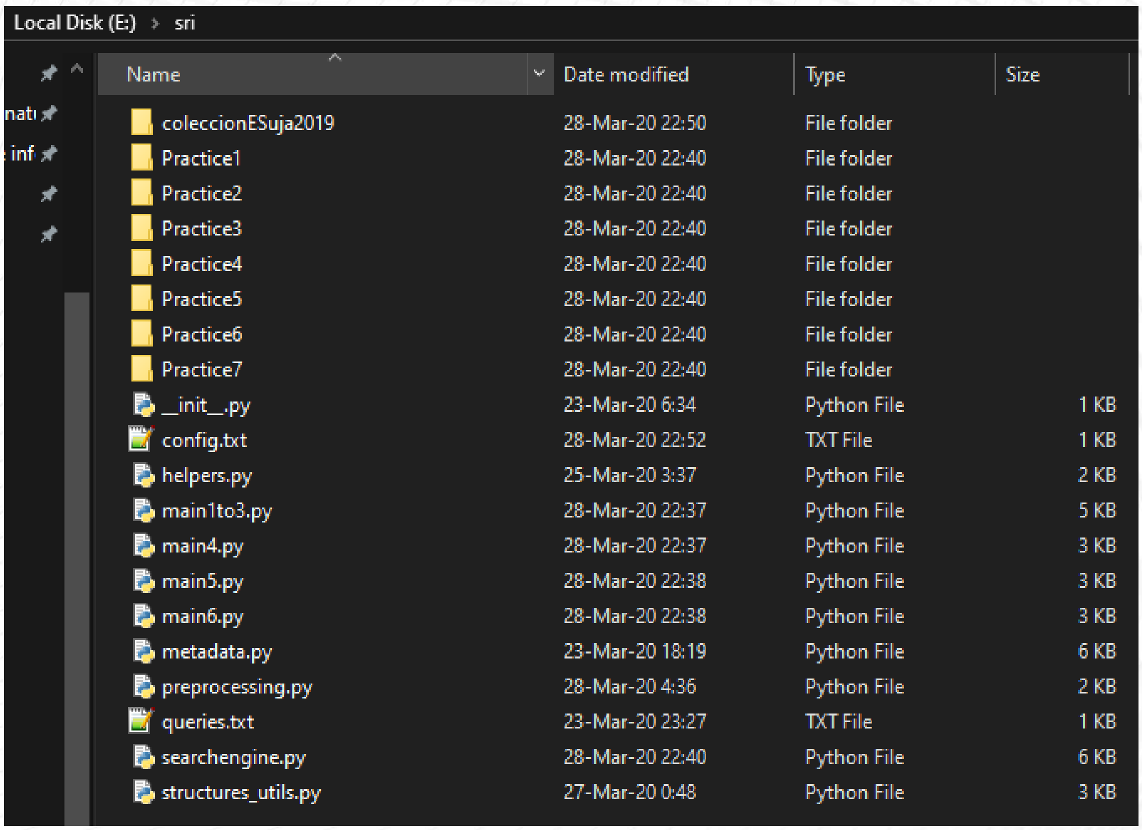


Figure 3.0 – Config file



Local Disk (E:) › sri

Name	Date modified	Type	Size
coleccionESuja2019	28-Mar-20 22:50	File folder	
Practice1	28-Mar-20 22:40	File folder	
Practice2	28-Mar-20 22:40	File folder	
Practice3	28-Mar-20 22:40	File folder	
Practice4	28-Mar-20 22:40	File folder	
Practice5	28-Mar-20 22:40	File folder	
Practice6	28-Mar-20 22:40	File folder	
Practice7	28-Mar-20 22:40	File folder	
__init__.py	23-Mar-20 6:34	Python File	1 KB
config.txt	28-Mar-20 22:52	TXT File	1 KB
helpers.py	25-Mar-20 3:37	Python File	2 KB
main1to3.py	28-Mar-20 22:37	Python File	5 KB
main4.py	28-Mar-20 22:37	Python File	3 KB
main5.py	28-Mar-20 22:38	Python File	3 KB
main6.py	28-Mar-20 22:38	Python File	3 KB
metadata.py	23-Mar-20 18:19	Python File	6 KB
preprocessing.py	28-Mar-20 4:36	Python File	2 KB
queries.txt	23-Mar-20 23:27	TXT File	1 KB
searchengine.py	28-Mar-20 22:40	Python File	6 KB
structures_utils.py	27-Mar-20 0:48	Python File	3 KB

Figure 3.1 – E:\sri\ (the location of the project, before first execution)

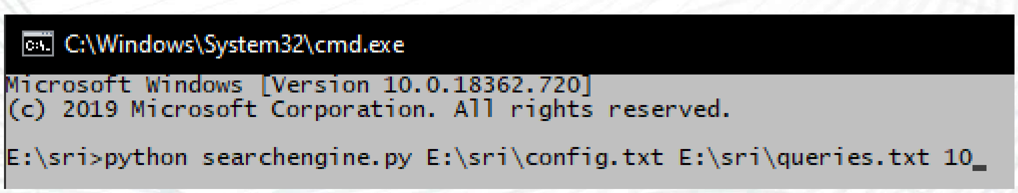


Figure 3.2 – How to execute the script

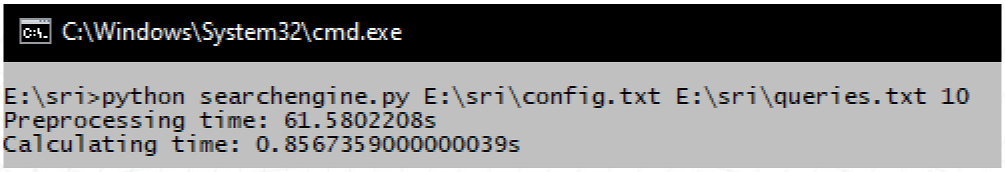


Figure 3.3 – Executing the script for the first time, index is created from the supplied collection

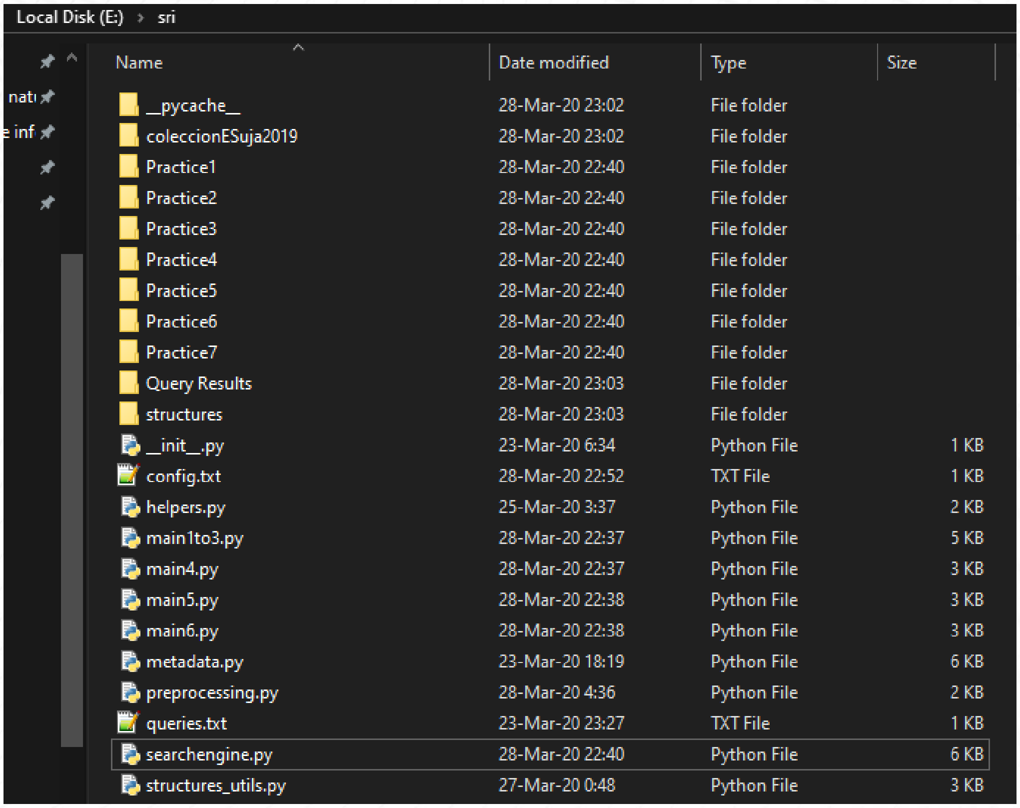


Figure 3.4 – Project folder after the execution (Query Results and structures folders are created)

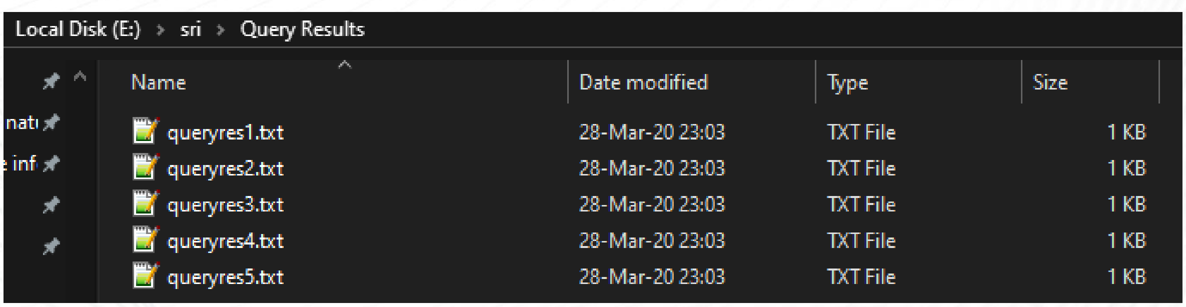


Figure 3.5 – Query Results folder

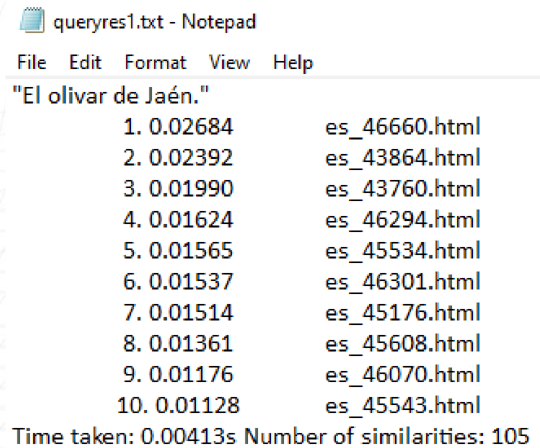


Figure 3.6 – Result file for the first query

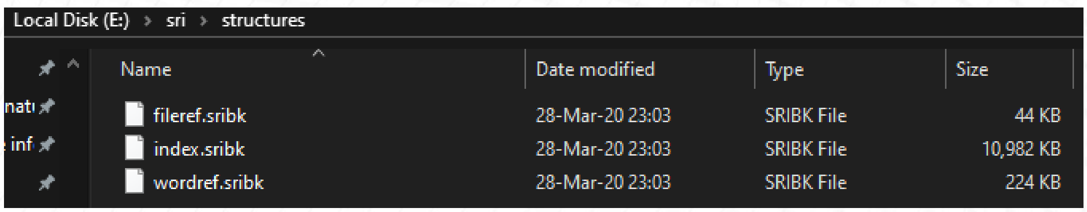


Figure 3.7 – structures folder, files contained are created after the first script execution

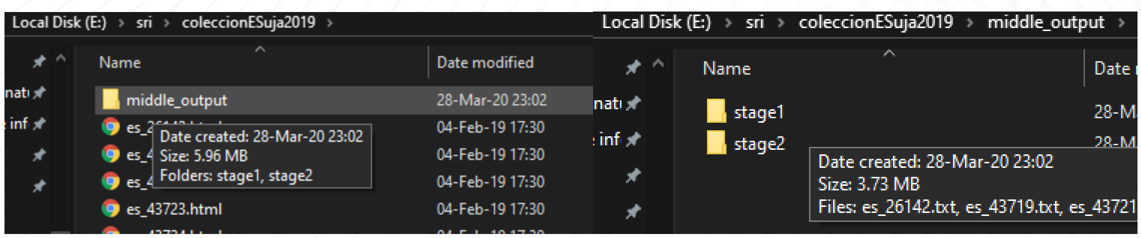


Figure 3.8 – middle_output folder inside the collection folder and its contents

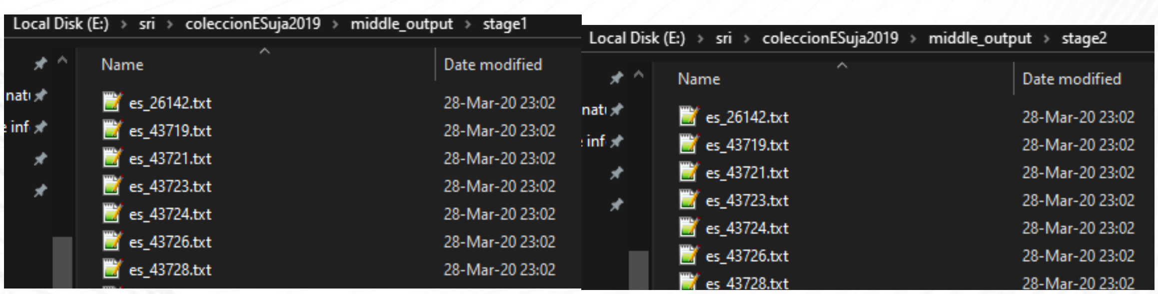


Figure 3.9 – contents of the stage1 and stage2 middle outputs

Conclusion

I am pleased with the design of the project and its structure so far. Two functionalities that I would like to add are the addition of new files to the index and the expansion of the collection of stoppers and stemmers so that it can process multiple languages. I would also like to do more detailed tests on the performance of the index and try different optimizations, including multi-threading.

The goal of this project was to create a simple search engine. I believe that I have managed to accomplish this and create an adequate report along with it. My experience with Python before this was very limited and I can say that I have learned a lot during the development of this project.