Assignment 1 Document Analysis 2021 Semester 2

In this assignment, your task is to index a document collection into an inverted index, and then measure search performance based on predefined queries.

A document collection containing more than 30,000 government site descriptions is provided for this assignment, along with a set of queries (*gov/topics/gov.topics*) and the expected returned documents (*gov/qrels/gov.qrels*). The provided code implements most of an information retrieval system. This provided code is designed to be simple to understand and modify, it is not efficient nor scalable. When developing a real-world IR system you would be better off using high performance software such as Apache Lucene.

Throughout this assignment:

1. You will develop a better understanding of indexing, including the tokenizer, parser, and normaliser components, and how to improve the search performance given a predefined evaluation metric,
2. You will develop a better understanding of search algorithms, and how to obtain better search results, and
3. You will find the best way to combine an indexer and search algorithm to maximise your performance.

Throughout this assignment you will make changes to the provided code to improve the information retrieval system. In addition, you will produce an answers file with your responses to each question. Your answers file must be a .pdf file named u1234567.pdf where u1234567 is your Uni ID. You should submit both your modified code files and answer pdf inside a single zip file. Do not submit the data or your built index **only submit the code and your answer pdf.**

Your answers to coding questions will be marked based on the quality of your code (is it efficient, is it readable, is it extendable, is it correct) and the solution in general (is it appropriate, is it reliable, does it demonstrate a suitable level of understanding).

Your answers to discussion questions will be marked based on how convincing your explanations are (are they sufficiently detailed, are they well-reasoned, are they backed by appropriate evidence, are they clear, do they use appropriate aids such as tables and plots where necessary).

Question 1: Implement the Indexer and Evaluate (25%)

Your first task is to implement index construction. You should complete the function stub *index_from_tokens* in *indexer.py* . This function takes as input a sorted list of tuples of the form (token_string, doc_id), indicating that the token token_string was in the document represented by doc_id. For each occurrence of a token in a document there is a tuple in this list – this means duplicate tuples indicate term count. **The input list is sorted in ascending order by token_string then doc_id.** Once complete the *index_from_tokens* function should output two dictionaries, the first *index* is a mapping from token strings to a sorted list of (doc_id, term_frequency) tuples. These lists should have their elements sorted in ascending order by doc_id, and contain only unique doc_ids – duplicates are used to compute term frequency. The second dictionary *doc_freq* is a mapping from token_string to document frequency.

Once you have implemented *index_from_tokens* you should run *indexer.py* to store the index, then run *query.py* to run a set of test queries, finally run *evaluate.py* to evaluate the query results against the ground truth. Record your evaluation results in your answers pdf file and make sure you submit your code.

Example Input for *index_from_tokens*:

[("cat", 1), ("cat", 1), ("cat", 2), ("door", 1), ("water", 3)]

Example Output for *index_from_tokens*:

index: {'cat': [(1, 2), (2, 1)], 'door': [(1, 1)], 'water': [(3, 1)]}

doc_freq: {'cat': 2, 'door': 1, 'water': 1}

Question 2: Implement TF-IDF Cosine Similarity (25%)

Currently *query_tfidf.py* uses cosine similarity applied to term frequency (it is currently a copy of *query.py* but you will change that). Your task is to implement cosine similarity applied to TF-IDF. In your solution both the query and the document vectors should be TF-IDF vectors. You will need to modify the *run_query* function and the *get_doc_to_norm* both of which are in *query_tfidf.py*.

The TF-IDF variant you should implement is:

$$TF-IDF = n_t * \ln\frac{N}{1+n_d}$$

Where n_t is the term frequency, n_d is the document frequency, and N is the total number of documents in the collection. This is almost the standard TF-IDF variant, except that 1 is added to the document frequency is to avoid division by zero errors.

Once you have implemented TF-IDF cosine similarity, run the *query_tfidf.py* file and record the results in your answers pdf file. Make sure you submit your code.

Question 3: Explore Linguistic Processing Techniques (25%)

For this question you will explore ways to improve the *process_tokens* function in *string_processing.py*. The current function removes stopwords. You should modify the function and explore the results. To modify the function, you should make changes to the functions *process_token_1*, *process_token_2*, and *process_token_3* and then uncomment the one you want to test within the main *process_tokens* function. You should pick at **least three different modifications** and evaluate them (you can add new process tokens functions if you want to evaluate more than three modifications). See lectures from some possible modifications. You might find the python *nltk* library useful. The modifications you make do not need to require significant coding, the focus of this question is choosing reasonable modifications and explaining the results.

Note: for this question you should use the unmodified *query.py* file. Do not use your TF-IDF implementation.

For each of the modification you make you should describe in your answers pdf file:

- What modifications you made.
- Why you made them (in other words why you though they might work)
- What the new performance is.
- Why you think the modification did/did not work. Making sure to give (and explain) examples of possible failure or success cases.

Finally, you should **compare all the modifications** using **one** appropriate metric and decide which modification (or combination of modifications) performed the best. Your comparison should **make use of a table or chart** as well as some **discussion**. Make sure to report all of this and your justification in your answer pdf file.

Make sure to submit all your code showing each of the changes you made.

Question 4: Implement Boolean Queries (25%)

Your task is to implement the ability to run boolean queries on the existing index. The starting code is provided in *query_boolean.py* . Specifically, you will implement a simplified boolean query grammar. You may assume that input queries consist of only "AND" and "OR" operators separated by single tokens. For example, "cat AND dog" is a valid query while "cat mask AND dog" is not a valid query since "cat mask" is not a single token. You are not required to implement "NOT". The order of operations will be left to right with no precedence for either of the operators, for example the query "cat AND dog OR fish AND fox" should be done in the following order: "((cat AND dog) OR fish) AND fox". The brackets are provided as an example; you can assume that the queries provided to your system will not contain brackets. To score full marks on this question, your solution should implement O(n + m) sorted list intersection and sorted list union algorithms – O(n + m) sorted list intersection was covered in the lectures, while union is very similar. Where n and m refer to the lengths of the two lists. Solutions using data structures such as sets or dictionaries to implement the intersection and union operations will not score full marks.

Once you have completed your boolean query system please run it on the following queries and list the relative paths (e.g. "./gov/documents/92/G00-92-0775281") of the retrieved documents in your answers pdf file (HINT: none of the queries below give more than 10 results, and Query 0 has been done for you so that you can check your system). Please **double check** that you are **not** using an index built with a modified version of *process_tokens* in *string_processing.py.*

Query0: “Welcoming”

Answer:

- ./gov/documents/31/G00-31-2565694
- ./gov/documents/42/G00-42-4180551
- ./gov/documents/85/G00-85-0255215
- ./gov/documents/86/G00-86-2161870
- ./gov/documents/86/G00-86-4087434
- ./gov/documents/97/G00-97-2878104
- ./gov/documents/98/G00-98-1962568

Query1: “unwelcome OR sam”

Query2: “ducks AND water”

Query3: “plan AND water AND wage”

Query4: “plan OR record AND water AND wage”

Query5: "space AND engine OR football AND placement"

Make sure you submit your code for this question as well as your answers.

Question 5: Evaluating IR Systems (25%)

Put your answers to the following two questions in your answers pdf file.

a. Explain how you can evaluate your boolean query system. Your answer should at a minimum consider: what data you would need (e.g. queries and ground truth), the challenges that you would have to face getting this data, what metrics are appropriate, and why these metrics are appropriate.
b. Now consider the case where the output of your boolean query system is going to be re-ranked and only the top 10 results displayed. Explain how you could evaluate this combined boolean query and re-ranking system. Your answer should at a minimum consider: what data you would need (e.g. queries and ground truth), the challenges that you would have to face getting this data, what metrics are appropriate, and why these metrics are appropriate.