

A Simple Search Engine

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Document Collection for Search Engine

- Now that we have a documents, let's represent a collection of documents for search.
- What does a such a class for representing a document collection need?
 - ▶ Information to store?
 - ▶ Functionality?

Document Collection for Search Engine

What does a class need for representing a document collection for search?

- Information to store:
 - ▶ Store the **documents**, and access them via an **id**.
 - ▶ An **inverted index**: A map from each term to all documents containing that term. (For efficiently finding all potentially relevant documents)
 - ▶ The **document frequency** for each terms (number of documents in which it occurs), to be used in similarity computation.
- Functionality:
 - ▶ **Read documents** (from directory)
 - ▶ **Return (all) documents** that contain (all) terms of a **query**.
 - ▶ **Reweight token frequencies** by tf-idf weighting.
 - ▶ Compute **cosine-similarity** for two documents.

Document Collection (Code Skeleton)

```
class DocumentCollection:
    def __init__(self, term_to_df, term_to_docids, \
        docid_to_doc):
        #...

    @classmethod
    def from_dir(cls, root_dir, file_suffix):
        #...

    @classmethod
    def from_document_list(cls, docs):
        #...

    def docs_with_all_tokens(self, tokens):
        #...

    def tfidf(self, counts):
        #...

    def cosine_similarity(self, docA, docB):
        #...
```

Detail: Constructor

- Set all the required data fields

```
def __init__(self, term_to_df, term_to_docids, docid_to_doc):  
    # string to int  
    self.term_to_df = term_to_df  
    # string to set of string  
    self.term_to_docids = term_to_docids  
    # string to TextDocument  
    self.docid_to_doc = docid_to_doc
```

Detail: Get all documents containing all search terms

```
def docs_with_all_tokens(self, tokens):  
    docids_for_each_token = [self.term_to_docids[token] \  
        for token in tokens]  
    docids = set.intersection(*docids_for_each_token)  
    return [self.docid_to_doc[id] for id in docids]
```

- What does `docids_for_each_token` contain?
- What is contained in `docids`?
- How can we get all documents that contain **any** of the search terms?
- Bonus: What could be (*roughly*) the time complexity of `set.intersection(...)`?

Detail: Get all documents containing all search terms

- What does `docids_for_each_token` contain?
List of set of document ids. (For each search term one set)
- What is contained in `docids`?
The intersection of the above sets. The ids of those documents that contain all terms.
- How can we get all documents that contain **any** of the search terms?
Use set union instead of intersection.
- Bonus: What could be (roughly) the time complexity of `set.intersection(...)`? A simple algorithm would be:
 - ▶ For each document id in any of the sets check whether it is contained in all of the other sets.
 - ▶ If yes, add to result set.
 - ▶ You can assume that checking set inclusion, and adding to a set takes constant time.
 - ▶ Complexity: $O(nm)$, where n is number of search terms, m is number of document ids in all sets.
 - ▶ A more efficient algorithm would use sorted lists of document ids (posting lists).

Detail: Tf.Idf Weighting

```
def tfidf(self, counts):  
    N = len(self.docid_to_doc)  
    return {tok: tf * math.log(N/self.term_to_df[tok]) for  
            tok,tf in counts.items() if tok in self.term_to_df}
```

- Input (dictionary): term \Rightarrow counts of term in document
- Output (dictionary): term \Rightarrow weighted counts
- Remember formulas:
 - ▶ Term frequency is just the number of occurrences of the term (we use the simple, unnormalized version).
 - ▶ Inverse document frequency:

$$\log \frac{N}{df_t}$$

where N is the size of the document collection and df_t is the number of documents term t occurs in.

Detail: Cosine Similarity

```
def cosine_similarity(self, docA, docB):  
    weightedA = self.tfidf(docA.token_counts)  
    weightedB = self.tfidf(docB.token_counts)  
    dotAB = dot(weightedA, weightedB)  
    normA = math.sqrt(dot(weightedA, weightedA))  
    normB = math.sqrt(dot(weightedB, weightedB))  
    if normA == 0 or normB == 0:  
        return 0.  
    else:  
        return dotAB / (normA * normB)
```

- Input (dictionaries): term frequencies of two documents.
- Output: Cosine similarity of tf.idf weighted document vectors.
- How would dot helper function look like?
- What is the meaning of normA and normB?
- When can normA or normB be zero?

Detail: Cosine Similarity

- How would dot helper function look like?

```
def dot(dictA, dictB):  
    return sum([dictA.get(tok) * dictB.get(tok,0) for \  
                tok in dictA])
```

- What is the meaning of normA and normB?

Vector norm (l2). It is defined as the square root of the dot product of a vector with itself:

$$|v|_2 = \sqrt{\sum_i v_i^2}$$

Intuitively it measures the “length” of a document, and is high if a document contains many terms.

- When can normA or normB be zero? *When a query only contains out-of-vocabulary words (tfidf(...)) filters those words out).*

Putting it all together: Search Engine

- Most of the functionality is already contained in the `DocumentCollection` class.
- The search engine only has to
 - ▶ Preprocess (tokenize) the query.
 - ▶ Call the respective methods (e.g. `docs_with_all_tokens`, `cosine_similarity`)
 - ▶ Sort the results to put most similar results first.
 - ▶ Select some text snippets for displaying to the user.

Search Engine: Code Skeleton

```
class SearchEngine:
    def __init__(self, doc_collection):
        #...
    def ranked_documents(self, query):
        #...
    def snippets(self, query, document, window=50):
        #...
```

- See full implementation in the lecture repository.

Summary

- Representing
 - ▶ Text documents
 - ▶ Document collections
- Factory method constructors
- Retrieving documents
- Computing similarity
- ... Questions?