Basic Tokenizing, Indexing, and Implementation of Vector-Space Retrieval

Naïve Implementation

Convert all documents in collection D to tf-idf weighted vectors, $\boldsymbol{d_j}$, for keyword vocabulary V.

Convert query to a tf-idf-weighted vector $\boldsymbol{q}$.

For each $\boldsymbol{d_j}$ in D do

Compute score $s_j = \mathrm{cosSim}(\boldsymbol{d_j}, \boldsymbol{q})$

Sort documents by decreasing score.

Present top ranked documents to the user.

Time complexity: $O(|V| \cdot |D|)$ Bad for large V & D !

$|V| = 10{,}000$; $|D| = 100{,}000$; $|V| \cdot |D| = 1{,}000{,}000{,}000$

Practical Implementation

- Based on the observation that documents containing none of the query keywords do not affect the final ranking
- Try to identify only those documents that contain at least one query keyword
- Actual implementation of an inverted index

Step 1: Preprocessing

- Implement the preprocessing functions:
  - For tokenization
  - For stop word removal
  - For stemming

- Input: Documents that are read one by one from the collection
- Output: Tokens to be added to the index
  - No punctuation, no stop-words, stemmed

Step 2: Indexing

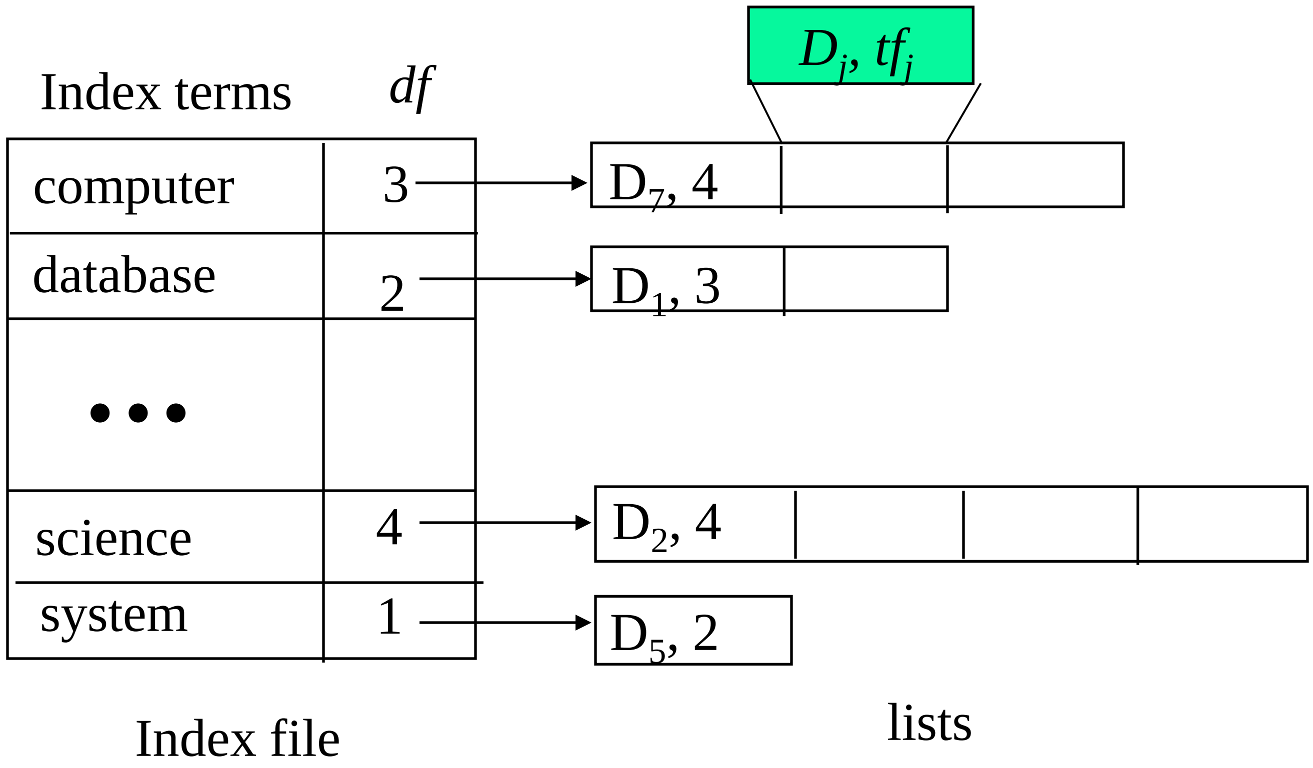
- Build an inverted index, with an entry for each word in the vocabulary

- Input: Tokens obtained from the preprocessing module
- Output: An inverted index for fast access

Step 2 (cont'd)

- Many data structures are appropriate for fast access
  - B-trees, sparse lists, hashtables
- We need:
  - One entry for each word in the vocabulary
  - For each such entry:
    - Keep a list of all the documents where it appears together with the corresponding frequency → TF
  - For each such entry, keep the total number of documents where the word occurred:
    - → IDF

Step 2 (cont'd)



Dj, tfj
Index terms
df
computer
3
D7, 4
database
2
D1, 3
• • •
science
4
D2, 4
system
1
D5, 2
Index file
lists

Step 2 (cont'd)

- Term frequencies and DF for each token can be computed in one pass
- Cosine similarity also requires the lengths of the document vectors.
- Might need a second pass (through document collection or the inverted index) to compute document vector lengths.

Step 2 (cont'd)

- Remember the weight of a token is: TF * IDF
- Therefore, must wait until IDF's are known (and therefore until all documents are indexed) before document lengths can be determined.
- Remember that the length of a document vector is the square-root of sum of the squares of the weights of its tokens.

- Do a second pass over all documents: keep a list or hashtable with all document id-s, and for each document determine the length of its vector.

Time Complexity of Indexing

- Complexity of creating vector and indexing a document of n tokens is $O(n)$.
- So indexing m such documents is $O(m\ n)$.
- Computing token IDFs can be done during the same first pass
- Computing vector lengths is also $O(m\ n)$.
- Complete process is $O(m\ n)$, which is also the complexity of just reading in the corpus.

Step 3: Retrieval

- Use inverted index (from step 2) to find the limited set of documents that contain at least one of the query words.
- Incrementally compute cosine similarity of each indexed document as query words are processed one by one.
- To accumulate a total score for each retrieved document, store retrieved documents in a hashtable, where the document id is the key, and the partial accumulated score is the value.

Step 3 (cont'd)

- Input: Query and Inverted Index (from Step2)
- Output: Similarity values between query and documents

Step 4: Ranking

- Sort the hashtable including the retrieved documents based on the value of cosine similarity
- Return the documents in descending order of their relevance
- Input: Similarity values between query and documents
- Output: Ranked list of documented in reversed order of their relevance

What weighting methods?

- Weights applied to both document terms and query terms
- Direct impact on the final ranking
- → Direct impact on the results
- → Direct impact on the quality of IR system

Standard Evaluation Measures

Starts with a CONTINGENCY table for each query

	retrieved	not retrieved	
relevant	TP	FN	$n_1 = TP + FN$
not relevant	FP	TN	
	$n_2 = TP + FP$		N

Precision and Recall

From all the documents that are relevant out there, how many did the IR system retrieve?

<u>Recall:</u>

$$\frac{TP}{TP + FN}$$

From all the documents that are retrieved by the IR system, how many are relevant?

<u>Precision:</u>

$$\frac{TP}{TP+FP}$$