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Inverted Index

- Preprocessing, Dictionary - Postings Lists, and Storage

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> Topics to be covered

- Recap:
  - IR systems
  - Classical Search Engines

- Keywords / User Information Needs
- Relevance / Irrelevance
- Personalization
- Words / Term Weighting

- Text Collection / Corpora
- Evaluation Strategy

- More topics to come up … Stay tuned …!!

Overview

Recap: Information Retrieval

- **Information Retrieval (IR)** is finding material (usually documents) of an unstructured nature (usually text) that satisfies an information need from within large collections (usually stored on computers).

- These days we frequently think first of web search, but there are many other cases:
  - E-mail search
  - Searching your laptop
  - Corporate knowledge bases
  - Legal information retrieval
  - and so on . . .

Statistics: Text Data

- How do we extract the term statistics?

Darjeeling is a city and a municipality

in the Indian state of West Bengal.

➔ Darjeeling – 1; is – 1; a – 1; city – 1; and – 1; a – 1; municipality – 1; in - 1; the – 1; Indian – 1; state – 1; of – 1; west – 1; Bengal – 1;

➔➔ Darjeeling – 1; is – 1; **a – 2**; city – 1; and – 1; municipality – 1; in - 1; the – 1; Indian – 1; state – 1; of – 1; west – 1; Bengal – 1;

Look at 3 documents

d_1- **Darjeeling** is a city and a municipality in the Indian state of West Bengal. It is located in the Lesser Himalayas at an elevation of 6,700 feet

d_2- **Darjeeling** is noted for its tea industry, its views of Kangchenjunga, the world's third-highest mountain, and the **Darjeeling** Himalayan Railway, a UNESCO World Heritage Site

d_3- **Darjeeling** is the headquarters of the **Darjeeling** District which has a partially autonomous status within the state of West Bengal. It is also a tourist destination in India

Unique words and Counts?

d_1	d_2	d_3
2 the	2 the	3 the
2 of	2 its	2 of
2 is	2 Darjeeling	2 is
2 in	1 world's	2 a
2 a	1 views	2 Darjeeling
1 state	1 third-highest	1 within
1 municipality	1 tea	1 which
1 located	1 of	1 tourist
1 feet	1 noted	1 status
1 elevation	1 mountain	1 state
1 city	1 is	1 partially
1 at	1 industry,	1 in
1 and	1 for	1 headquarters
1 an	1 and	1 has
1 West	1 a	1 destination
1 Lesser	1 World	1 autonomous
1 It	1 UNESCO	1 also
1 Indian	1 Site	1 West
1 Himalayas	1 Railway	1 It
1 Darjeeling	1 Kangchenjunga	1 India
1 Bengal	1 Himalayan	1 District
1 6,700	1 Heritag	1 Bengal

Documents – Words / Terms*

- How to construct Terms - documents

Doc ID	Terms	# Words
d_1	6,700 (1), Bengal. (1), Darjeeling (1), Himalayas (1), Indian (1), It (1), Lesser (1), West (1), a (2), an (1), and (1), at (1), city (1), elevation (1), feet (1), in (2), is (2), located (1), municipality (1), of (2), state (1), the (2),	22
d_2	Darjeeling (2), Heritage (1), Himalayan (1), Kangchenjunga, (1), Railway, (1), Site (1), UNESCO (1), World (1), a (1), and (1), for (1), industry, (1), is (1), its (2), mountain, (1), noted (1), of (1), tea (1), the (2), third-highest (1), views (1), world's (1),	22
d_3	Bengal. (1), Darjeeling (2), District (1), India (1), It (1), West (1), a (2), also (1), autonomous (1), destination (1), has (1), headquarters (1), in (1), is (2), of (2), partially (1), state (1), status (1), the (3), tourist (1), which (1), within (1),	22

NOTE: “**Words**” and “**Terms**” are interchangeably used throughout the course

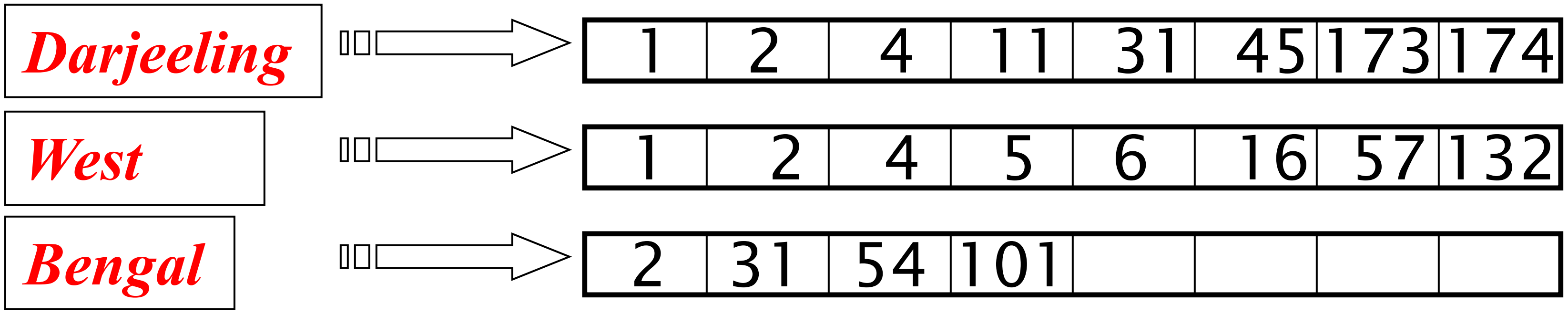
Terms - Documents

Terms	d_1	d_2	d_3	. . .	d_n
the	2	2	3	. . .	0
a	2	1	2	. . .	1
Darjeeling	1	2	2	. . .	0
is	2	1	2	. . .	0
of	2	1	2	. . .	0
in	2	0	0	. . .	1
and	1	1	0	. . .	0
Bengal	1	0	1	. . .	0
It	1	0	1	. . .	0
Its	0	2	0	. . .	2
state	1	0	1	. . .	0
West	1	0	1	. . .	1

NOTE: "**Words**" and "**Terms**" are interchangeably used throughout the course

Inverted index

- For each term t, we must store a list of all documents that contain t.
  - Identify each doc by a docID, a document serial number
- Can we used fixed-size arrays for this?

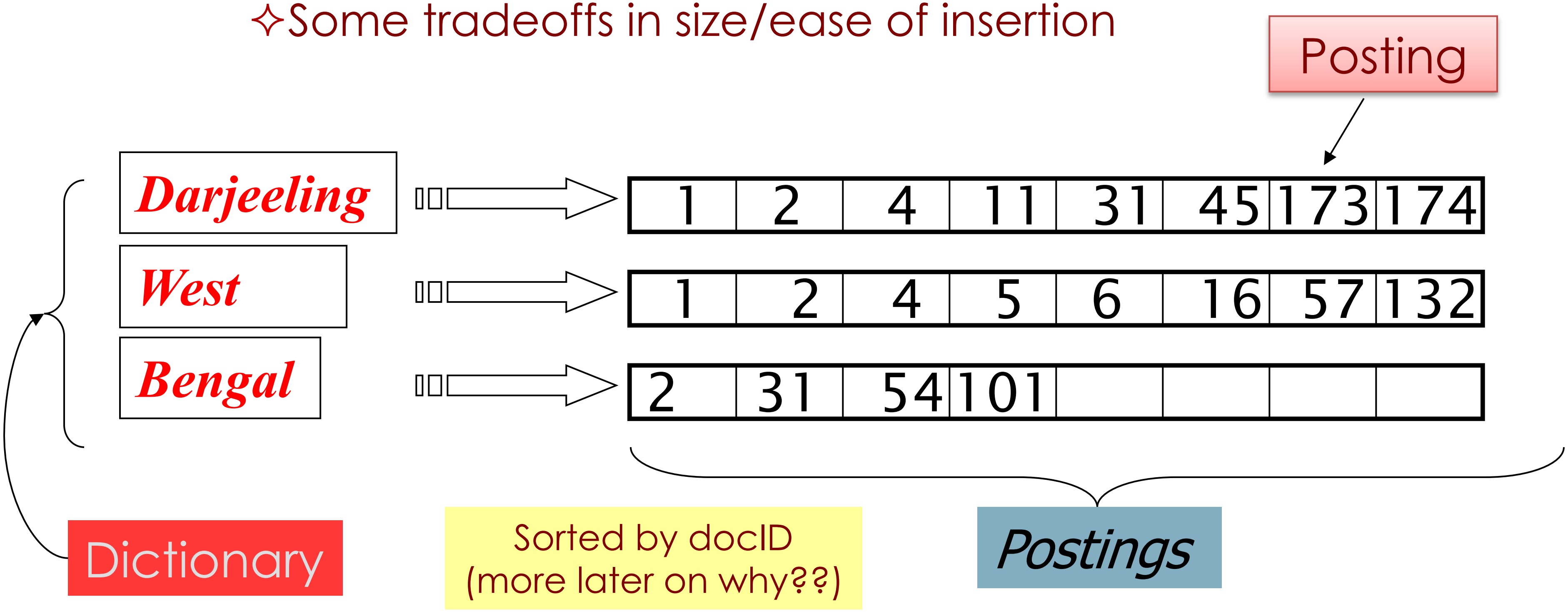


Darjeeling	1	2	4	11	31	45	173	174
West	1	2	4	5	6	16	57	132
Bengal	2	31	54	101				

What happens if the word ***Darjeeling*** is added to document 14?

Inverted index

- ✧ We need variable-size postings lists
  - ✧ On disk, a continuous run of postings is normal and best
  - ✧ In memory, can use linked lists or variable length arrays
    - ✧Some tradeoffs in size/ease of insertion



Posting

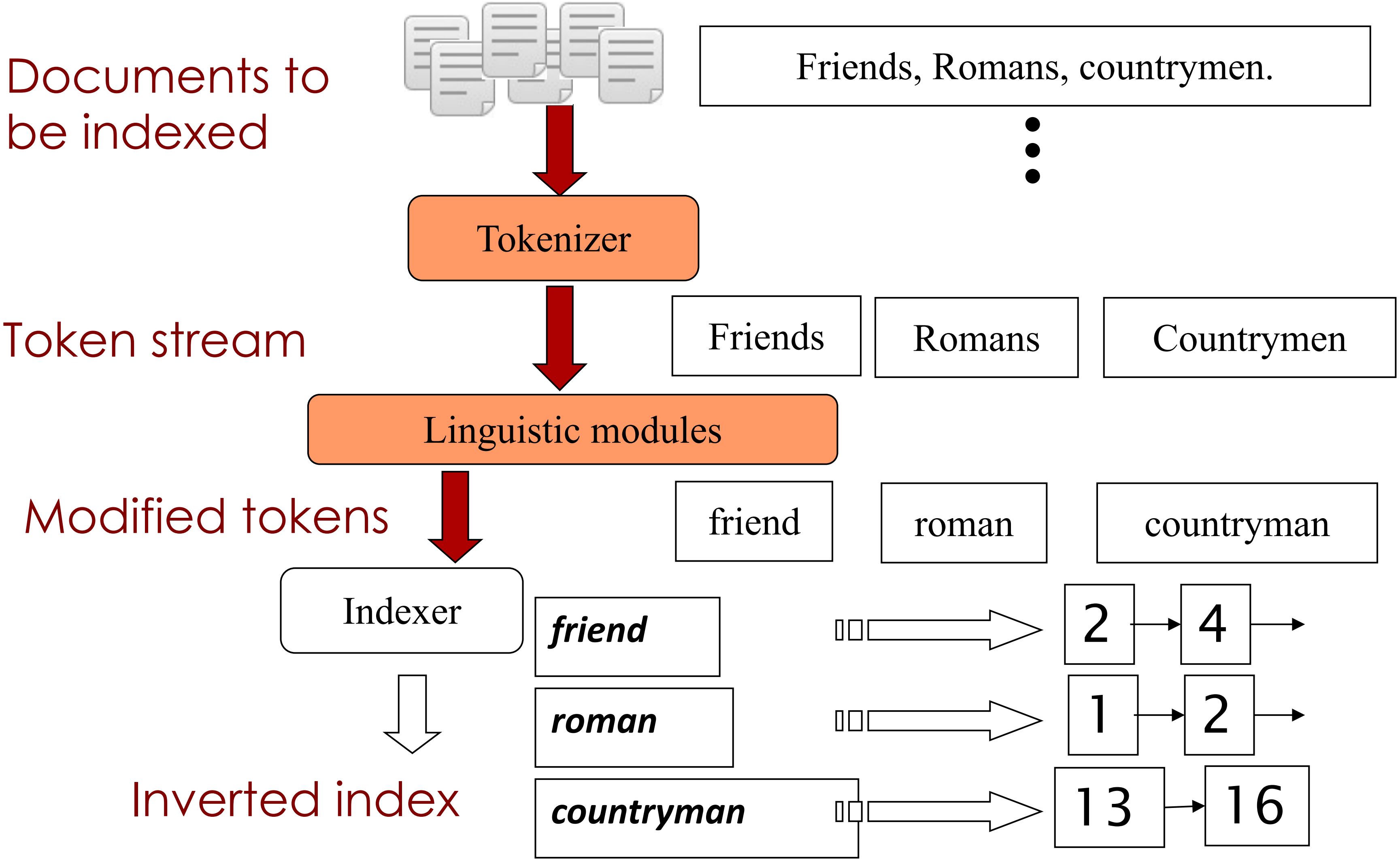
Darjeeling	1	2	4	11	31	45	173	174
West	1	2	4	5	6	16	57	132
Bengal	2	31	54	101				

Dictionary

Sorted by docID
(more later on why??)

Postings

Inverted index construction



Initial stages of text processing

- **Tokenization**
  - Cut character sequence into word tokens
    - Deal with “John’s”, a state-of-the-art solution

- **Normalization**
  - Map text and query term to same form
    - You want U.S.A. and USA to match

- **Stemming**
  - We may wish different forms of a root to match
    - authorize, authorization

- **Stop words**
  - We may omit very common words (or not)
    - the, a, to, of

Indexer steps: Token sequence

- Sequence of (Modified token, Document ID) pairs

Doc 1

I did enact Julius Caesar I was killed i’ the Capitol; Brutus killed me.

Doc 2

So let it be with Caesar. The noble Brutus hath told you Caesar was ambitious

Term	docID
I	1
did	1
enact	1
julius	1
caesar	1
I	1
was	1
killed	1
i'	1
the	1
capitol	1
brutus	1
killed	1
me	1
so	2
let	2
it	2
be	2
with	2
caesar	2
the	2
noble	2
brutus	2
hath	2
told	2
you	2
caesar	2
was	2
ambitious	2

Indexer steps: Sort

- Sort by terms
  - And then docID

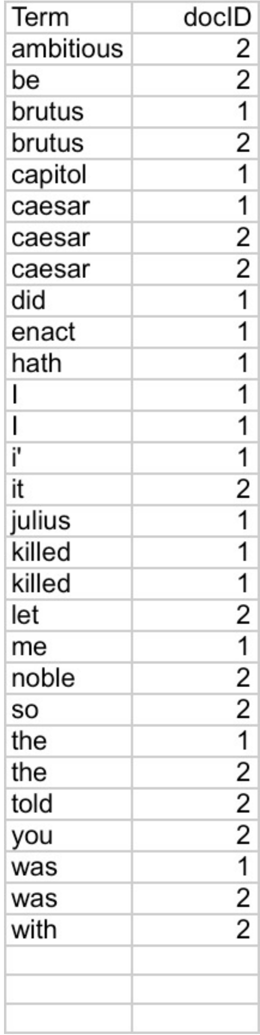
Core indexing step

Term	docID
I	1
did	1
enact	1
julius	1
caesar	1
I	1
was	1
killed	1
i'	1
the	1
capitol	1
brutus	1
killed	1
me	1
so	2
let	2
it	2
be	2
with	2
caesar	2
the	2
noble	2
brutus	2
hath	2
told	2
you	2
caesar	2
was	2
ambitious	2

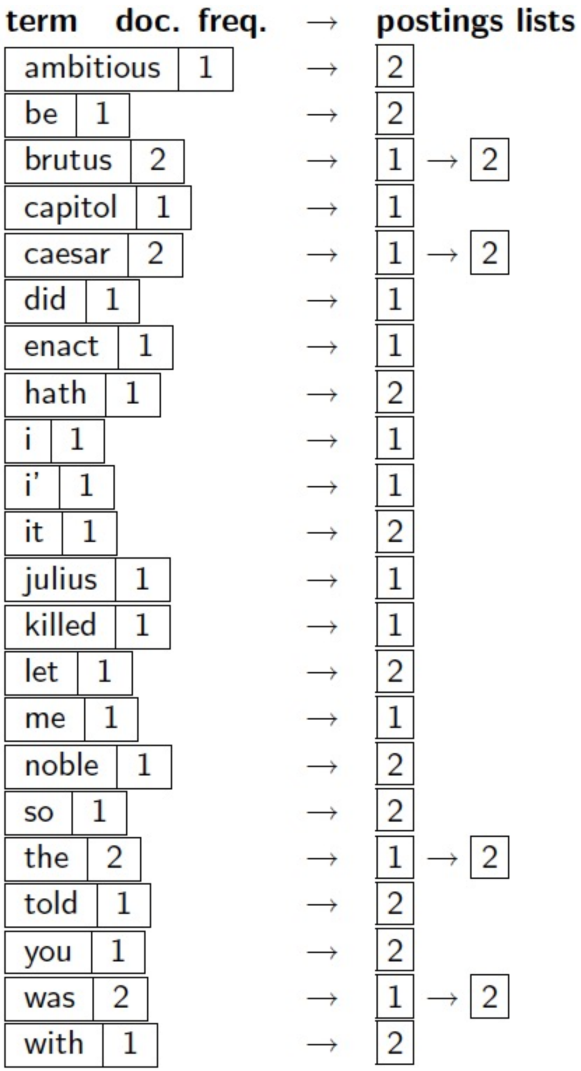
Term	docID
ambitious	2
be	2
brutus	1
brutus	2
capitol	1
caesar	1
caesar	2
caesar	2
did	1
enact	1
hath	1
I	1
I	1
i'	1
it	2
julius	1
killed	1
killed	1
let	2
me	1
noble	2
so	2
the	1
the	2
told	2
you	2
was	1
was	2
with	2

Indexer steps: Dictionary & Postings

- ✧ Multiple term entries in a single document are merged
- ✧ Split into Dictionary and Postings
- ✧ Doc. frequency information is added.

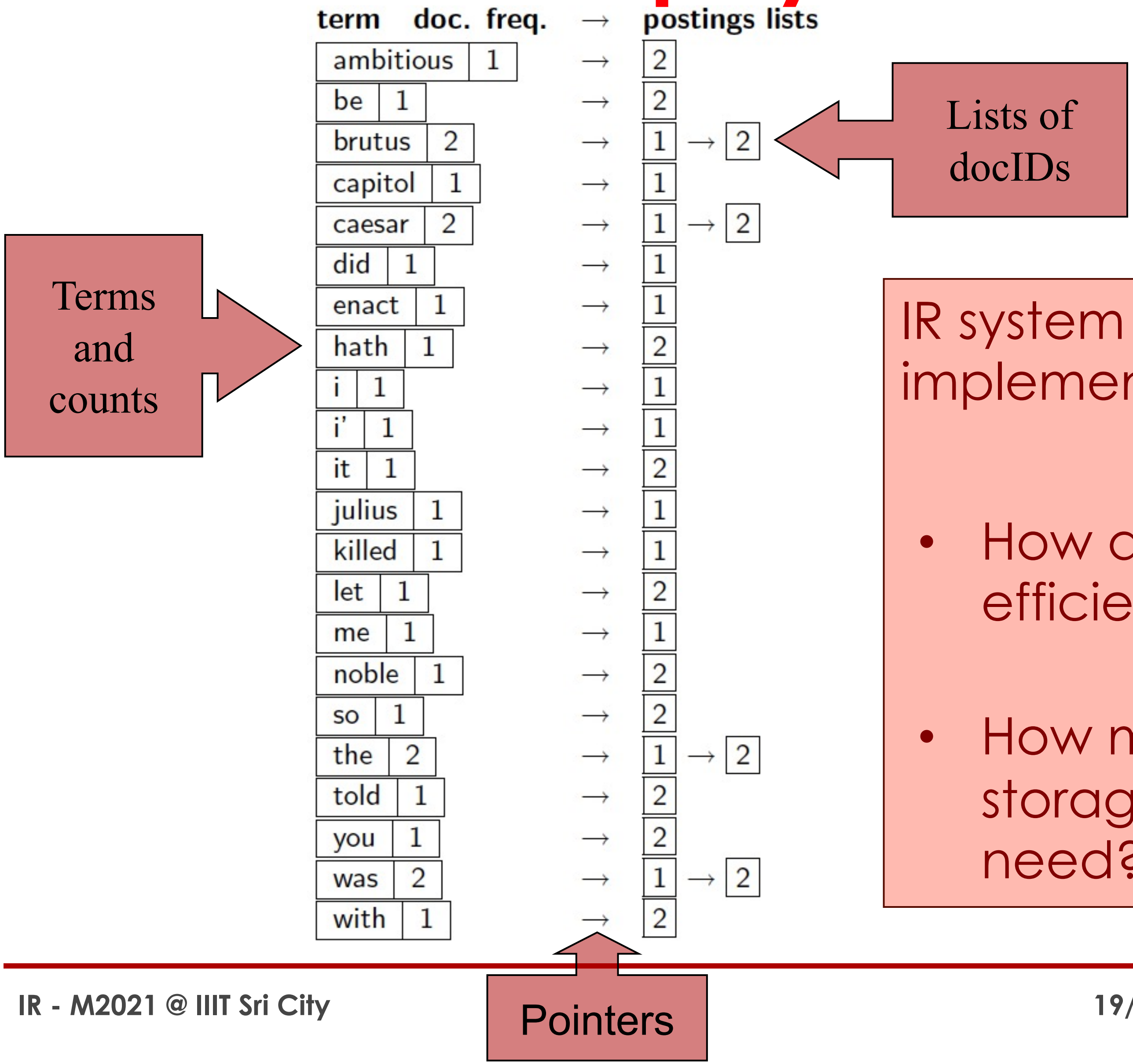


Term	docID
ambitious	2
be	2
brutus	1
brutus	2
capitol	1
caesar	1
caesar	2
caesar	2
did	1
enact	1
hath	1
I	1
I	1
i'	1
it	2
julius	1
killed	1
killed	1
let	2
me	1
noble	2
so	2
the	1
the	2
told	2
you	2
was	1
was	2
with	2



term	doc. freq.	→	postings lists
ambitious	1	→	2
be	1	→	2
brutus	2	→	1 → 2
capitol	1	→	1
caesar	2	→	1 → 2
did	1	→	1
enact	1	→	1
hath	1	→	2
i	1	→	1
i'	1	→	1
it	1	→	2
julius	1	→	1
killed	1	→	1
let	1	→	2
me	1	→	1
noble	1	→	2
so	1	→	2
the	2	→	1 → 2
told	1	→	2
you	1	→	2
was	2	→	1 → 2
with	1	→	2

Where do we pay in storage?



term	doc. freq.	→	postings lists
ambitious	1	→	2
be	1	→	2
brutus	2	→	1 → 2
capitol	1	→	1
caesar	2	→	1 → 2
did	1	→	1
enact	1	→	1
hath	1	→	2
i	1	→	1
i'	1	→	1
it	1	→	2
julius	1	→	1
killed	1	→	1
let	1	→	2
me	1	→	1
noble	1	→	2
so	1	→	2
the	2	→	1 → 2
told	1	→	2
you	1	→	2
was	2	→	1 → 2
with	1	→	2

Lists of docIDs

Terms and counts

Pointers

IR system implementation

- How do we index efficiently?
- How much storage do we need?

Ex: Create an Inverted Index

d1) Turing machines can define computational processes that do not terminate. The informal definitions of algorithms generally require that the algorithm always terminates. This requirement renders the task of deciding whether a formal procedure is an algorithm impossible in the general case

d2) Typically, when an algorithm is associated with processing information, data can be read from an input source, written to an output device and stored for further processing. Stored data are regarded as part of the internal state of the entity performing the algorithm.

d3) For some such computational process, the algorithm must be rigorously defined: specified in the way it applies in all possible circumstances that could arise. Any conditional steps must be systematically dealt with, case-by-case

Summary

In this class, we focused on:

(a) Words / Terms / Lexical Units

(b) Tokenizing the terms

(c) Preparing Term – Document matrix

(d) Inverted Index Construction

i. Dictionary and Postings Lists
ii. Merging the Postings
iii. How much storage is required?

Questions

It’s Your Time

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