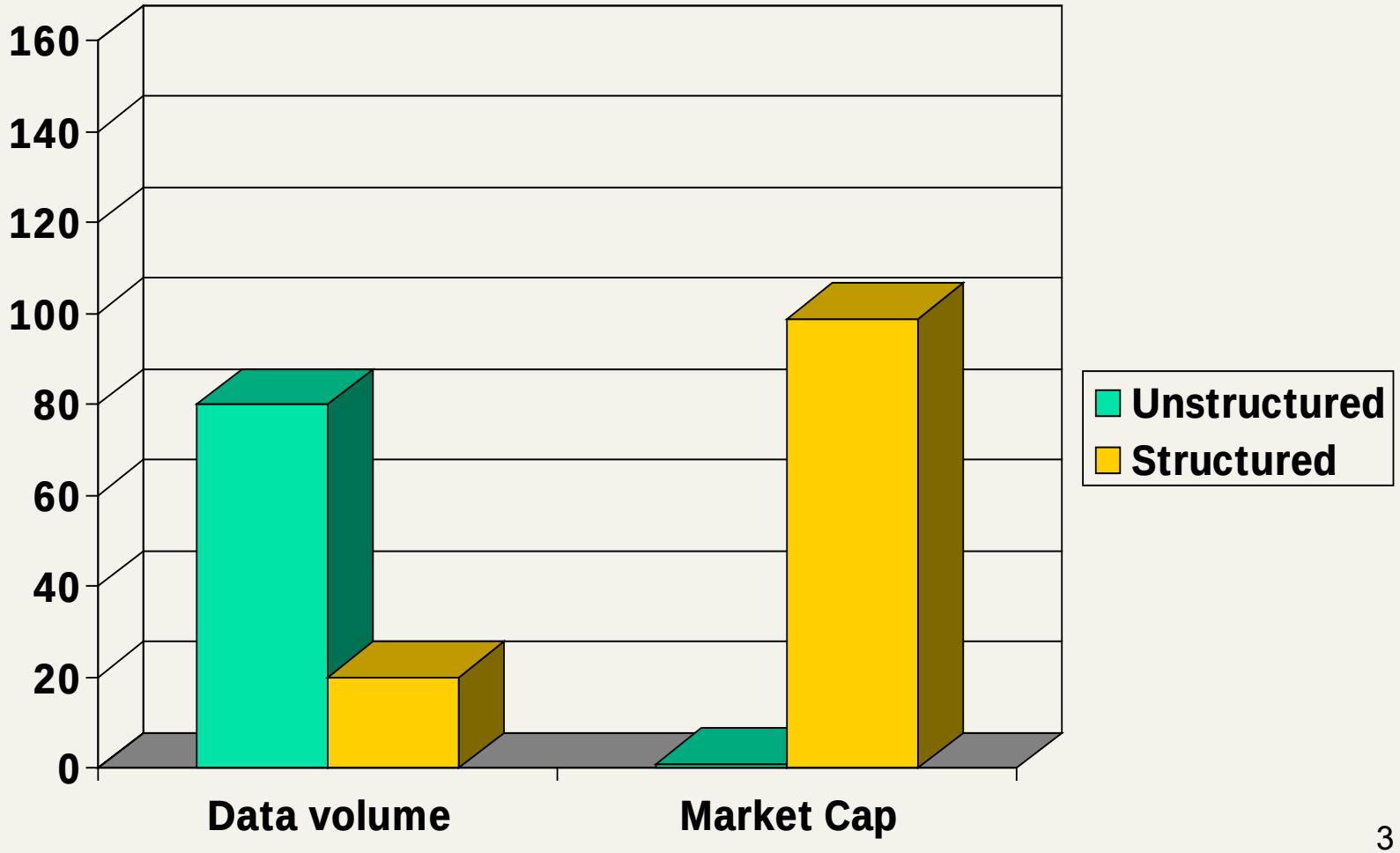
Boolean retrieval

Many thanks to Prabhakar Raghavan for sharing most content from the following slides

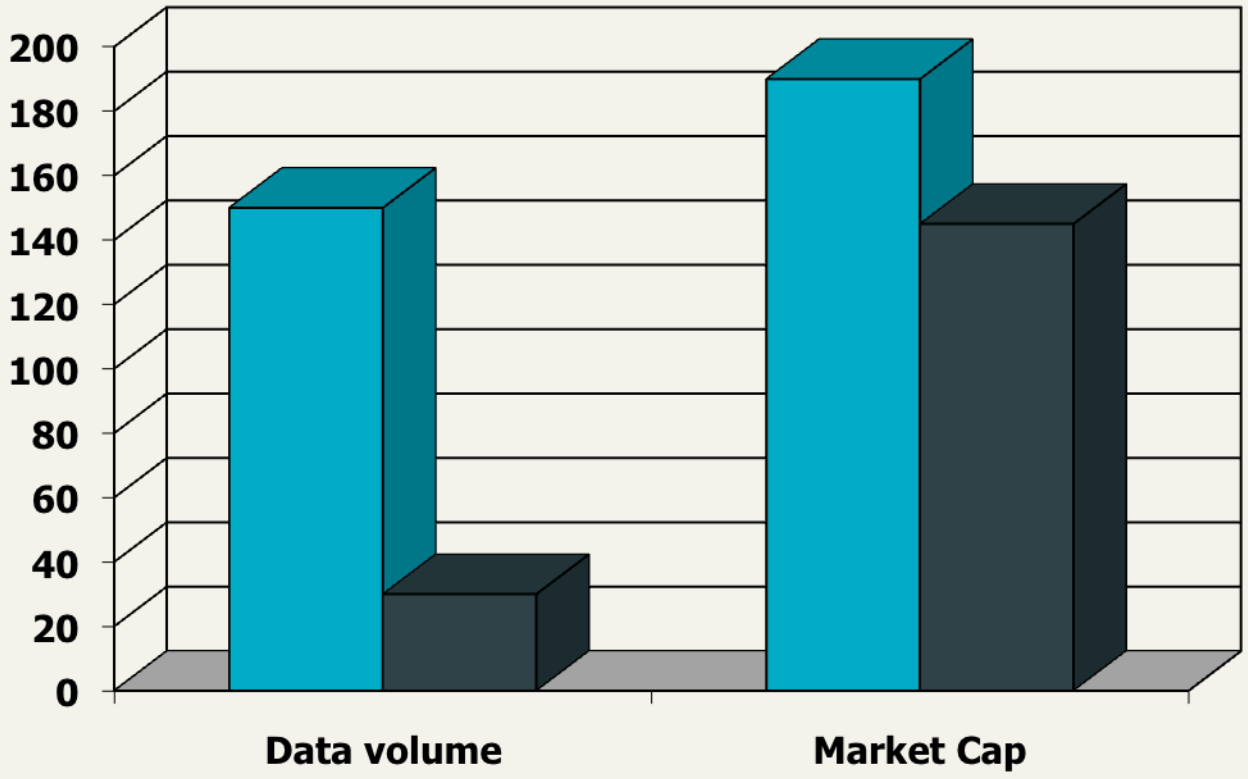
Information Retrieval

- 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).
  - Librarians
  - Now also in XML and DB
  - Focus on user

Unstructured (text) vs. structured (database) data in 1996



Unstructured (text) vs. structured (database) data in 2009



Google

YAHOO!

bing

Ask.com

Unstructured data in 1680

- Which plays of Shakespeare contain the words ***Brutus*** *AND* ***Caesar*** but *NOT* ***Calpurnia***?
- One could grep all of Shakespeare's plays for ***Brutus*** and ***Caesar,*** then strip out lines containing ***Calpurnia***?
  - Slow (for large corpora)
  - *NOT* ***Calpurnia*** is non-trivial
  - Other operations (e.g., find the word ***Romans*** near ***countrymen***) not feasible
  - Ranked retrieval (best documents to return) also hard
    - Later lectures

Solution: Term-document incidence

	Antony and Cleopatra	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth
Antony	1	1	0	0	0	1
Brutus	1	1	0	1	0	0
Caesar	1	1	0	1	1	1
Calpurnia	0	1	0	0	0	0
Cleopatra	1	0	0	0	0	0
mercy	1	0	1	1	1	1
worser	1	0	1	1	1	0

1 if play contains word, 0 otherwise

Brutus *AND* ***Caesar*** but *NOT* ***Calpurnia***

Incidence vectors

- So we have a 0/1 vector for each term.
- To answer query: take the vectors for ***Brutus,*** ***Caesar*** and ***Calpurnia*** (complemented) ➔ bitwise *AND*.
- 110100 *AND* 110111 *AND* 101111 = 100100.

Answers to query

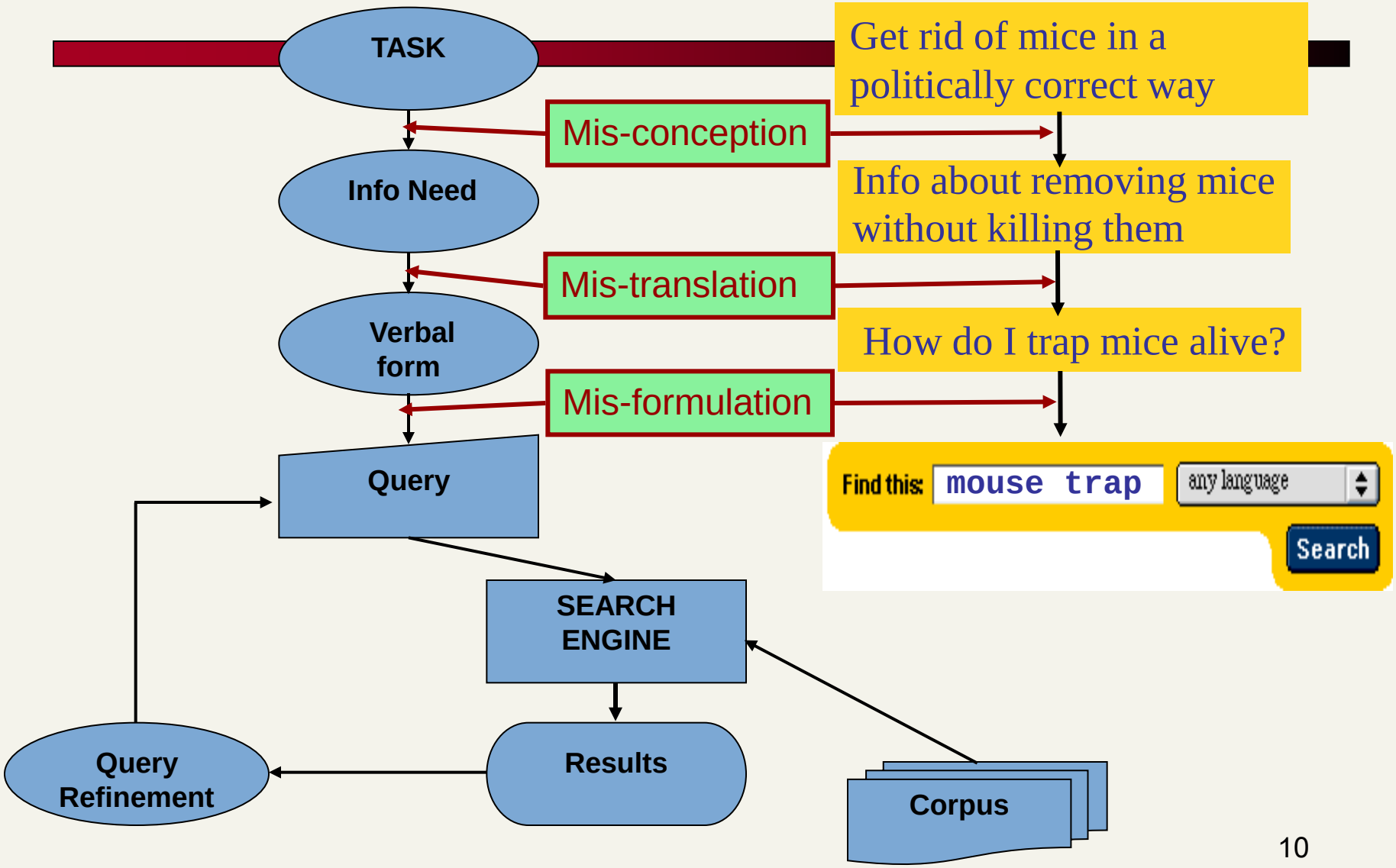
- Antony and Cleopatra, Act III, Scene ii
- *Agrippa* [Aside to DOMITIUS ENOBARBUS]: Why, Enobarbus,
- When Antony found Julius ***Caesar*** dead,
- He cried almost to roaring; and he wept
- When at Philippi he found ***Brutus*** slain.

- Hamlet, Act III, Scene ii
- *Lord Polonius:* I did enact Julius ***Caesar*** I was killed i' the
- Capitol; ***Brutus*** killed me.

Basic assumptions of Information Retrieval

- Corpus: Fixed document collection
- Goal: Retrieve documents with information that is relevant to user's information need and helps him complete a task

The classic search model



How good are the retrieved docs?

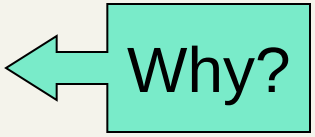
- *Precision* : Fraction of retrieved docs that are relevant to user's information need
- *Recall* : Fraction of relevant docs in corpus that are retrieved
- More precise definitions and measurements to follow in later lectures

Bigger corpora

- Consider *N* = 1M documents, each with about 1K terms.
- Avg. 6 bytes/term incl. spaces/punctuation (EN)
  - 6GB of data in the documents.
- Say there are *m* = 500K *distinct* terms among these.

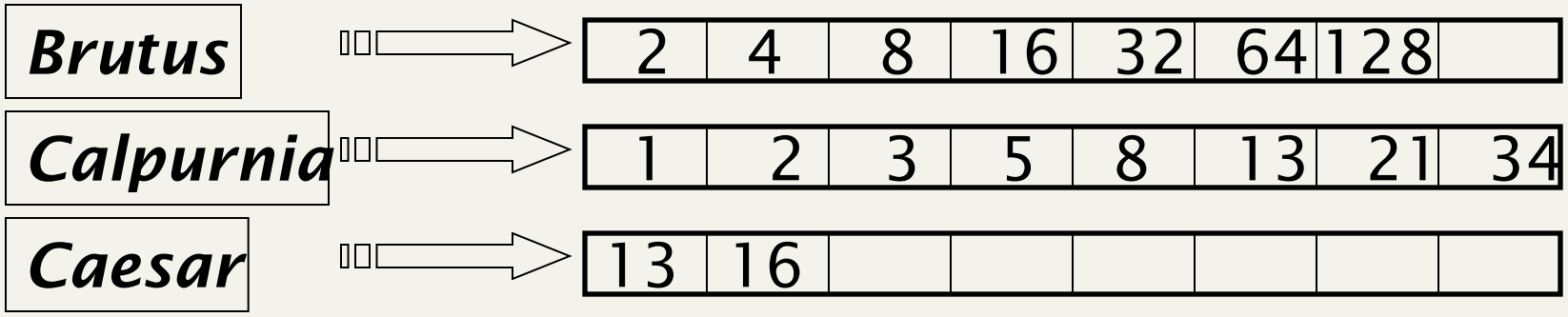
Can’t build the matrix

- 500K x 1M matrix has half-a-trillion 0’s and 1’s.
- But it has no more than one billion 1’s.
  - matrix is extremely sparse.
- What’s a better representation?
  - We only record the 1 positions.



Inverted index

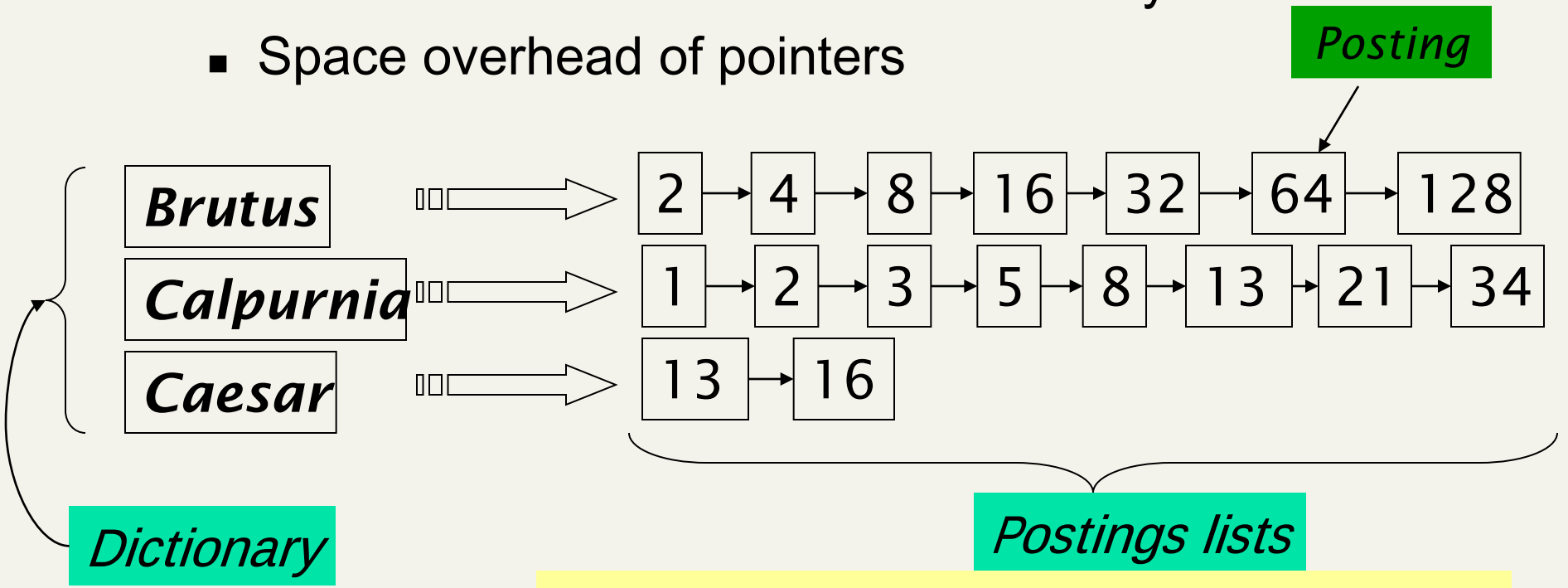
- For each term *T*, we must store a list of all documents that contain *T*.
- Do we use an array or a list for this?



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

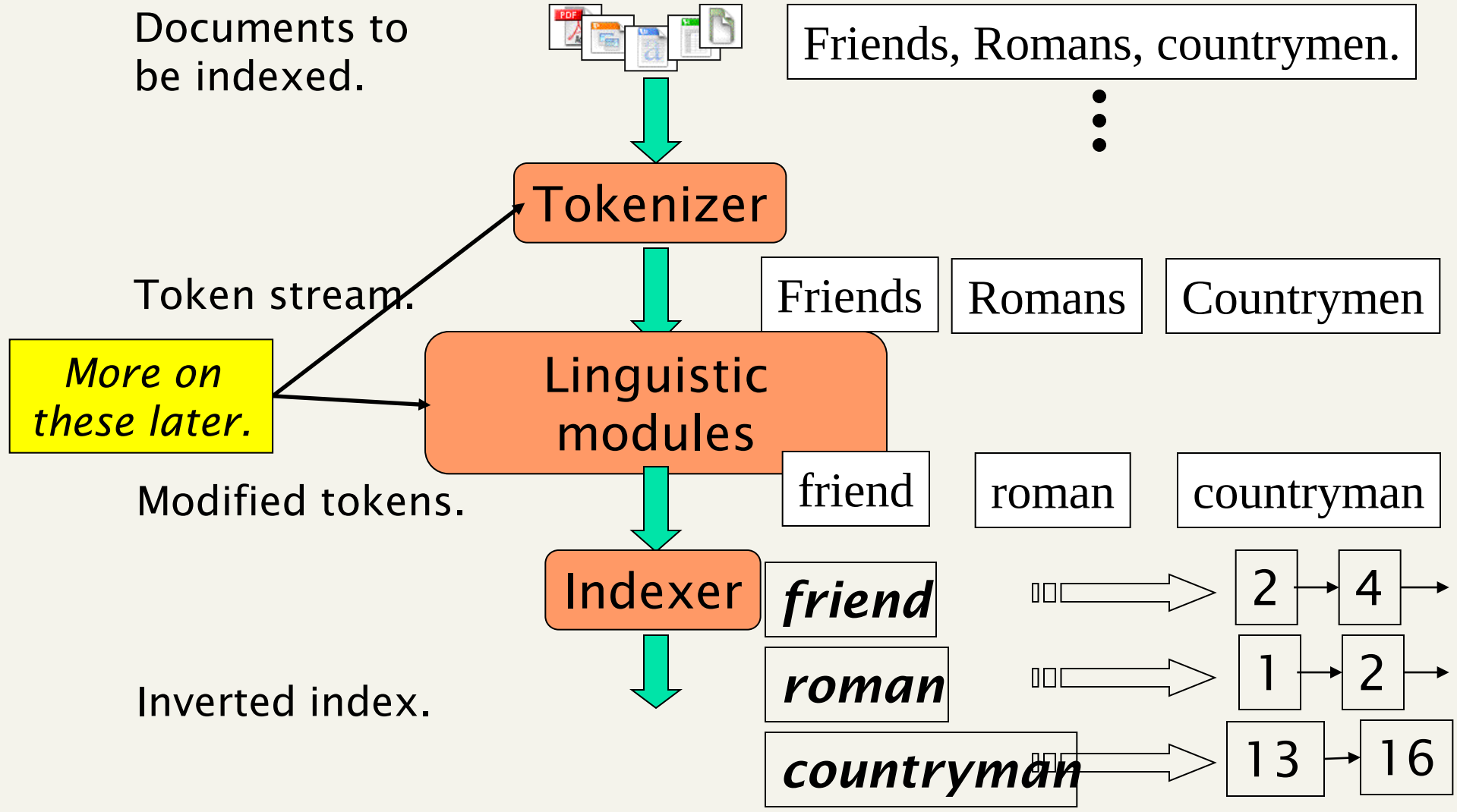
Inverted index

- Linked lists generally preferred to arrays
  - Dynamic space allocation
  - Insertion of terms into documents easy
  - Space overhead of pointers



Sorted by docID (more later on why).

Inverted index construction



Indexer steps

- 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	Doc #
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

- Sort by terms.

Core indexing step.

Term	Doc #
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

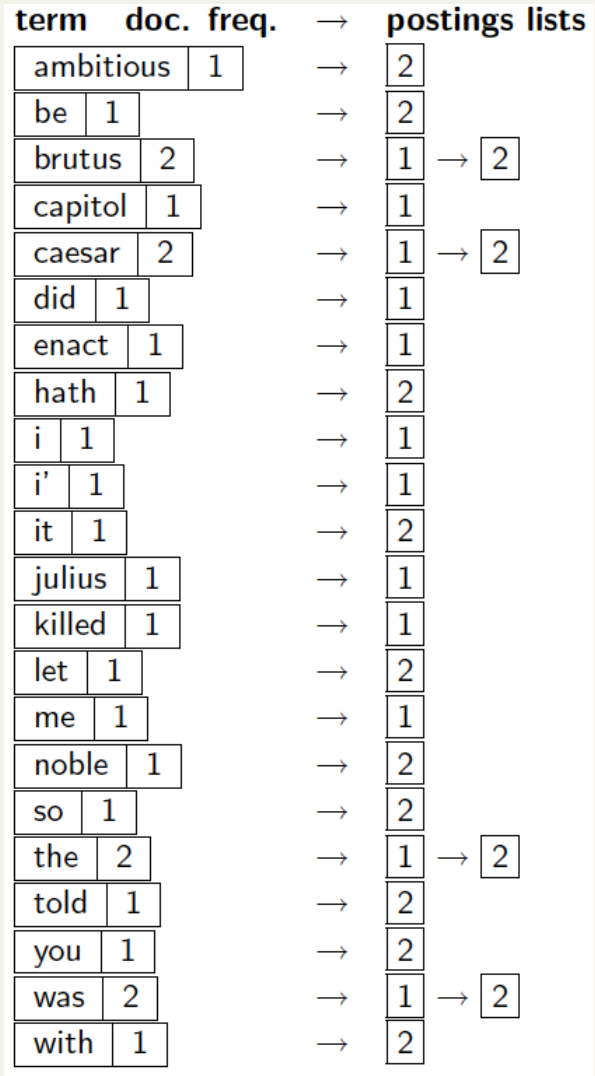
Term	Doc #
ambitious	2
be	2
brutus	1
brutus	2
capitol	1
caesar	1
caesar	2
caesar	2
did	1
enact	1
hath	1
I	1
I	1
i'	1
it	2
julius	1
killed	1
killed	1
let	2
me	1
noble	2
so	2
the	1
the	2
told	2
you	2
was	1
was	2
with	2

Indexer steps: Dictionary & Postings

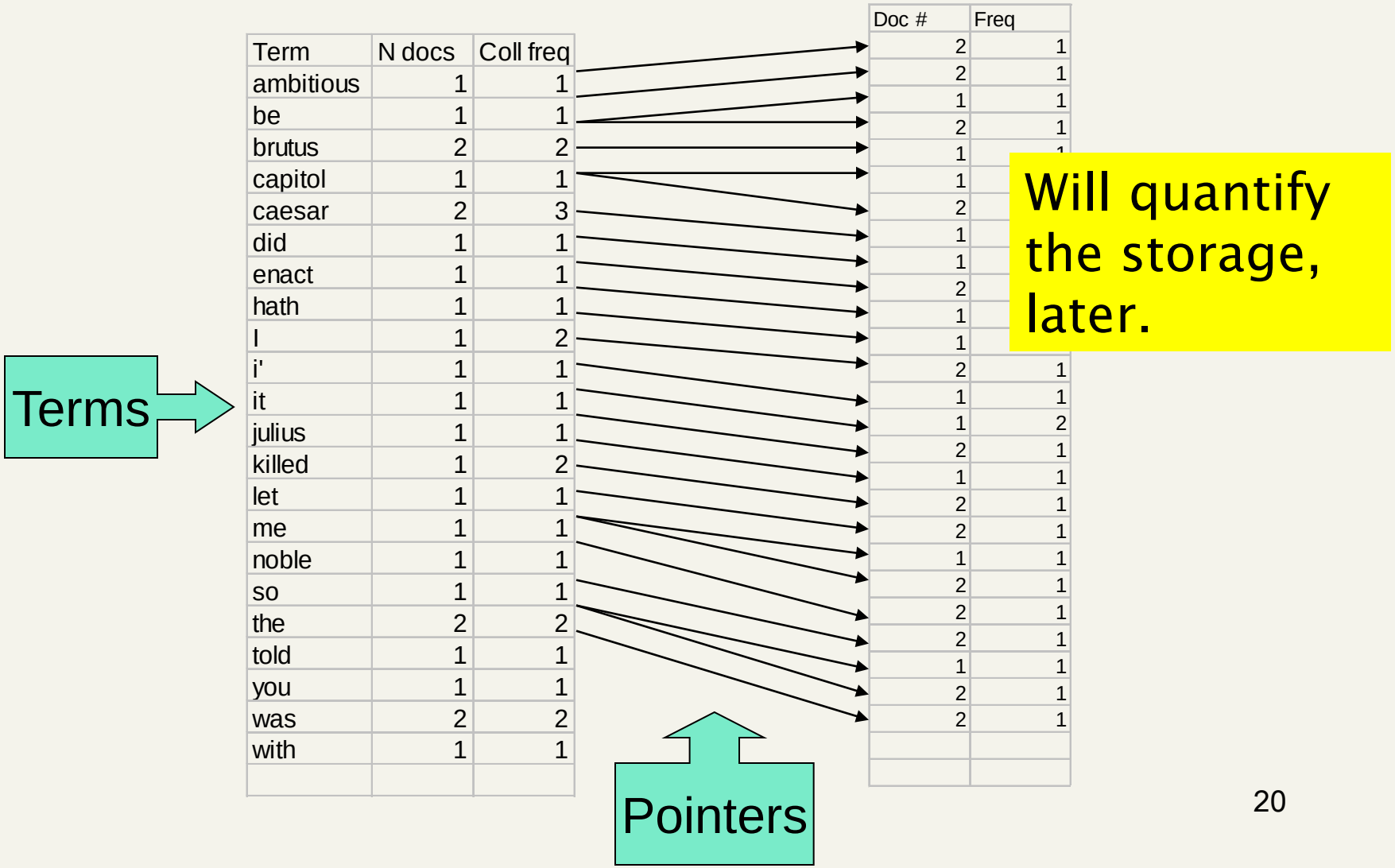
- Multiple term entries in a single document are merged.
- Split into Dictionary and Postings
- Doc. frequency information is added.

Why frequency? Will discuss later.

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



- Where do we pay in storage?

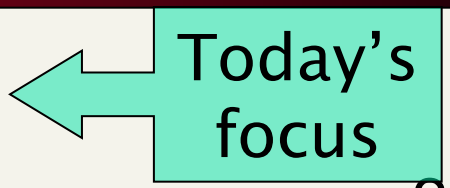


Term	N docs	Coll freq
ambitious	1	1
be	1	1
brutus	2	2
capitol	1	1
caesar	2	3
did	1	1
enact	1	1
hath	1	1
I	1	2
i'	1	1
it	1	1
julius	1	1
killed	1	2
let	1	1
me	1	1
noble	1	1
so	1	1
the	2	2
told	1	1
you	1	1
was	2	2
with	1	1

Doc #	Freq
2	1
2	1
1	1
2	1
1	1
1	1
2	1
1	1
1	1
2	1
1	1
1	1
2	1
1	1
1	2
2	1
1	1
2	1
2	1
1	1
2	1
2	1
2	1
1	1
2	1
2	1

The index we just built

- How do we process a query?
  - Later - what kinds of queries can we process?

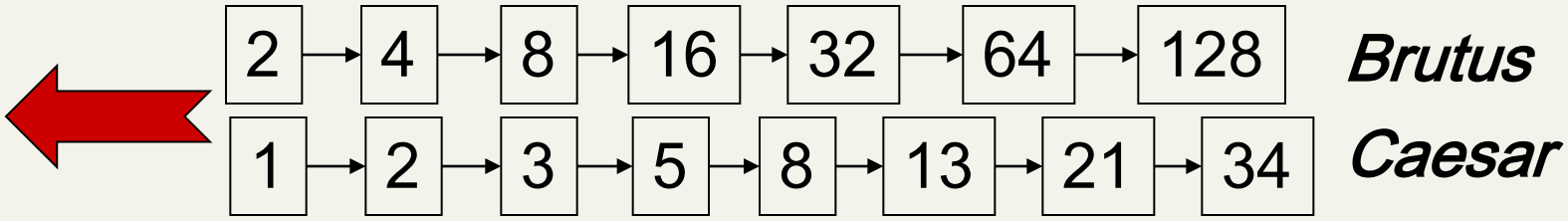


Query processing: AND

- Consider processing the query:

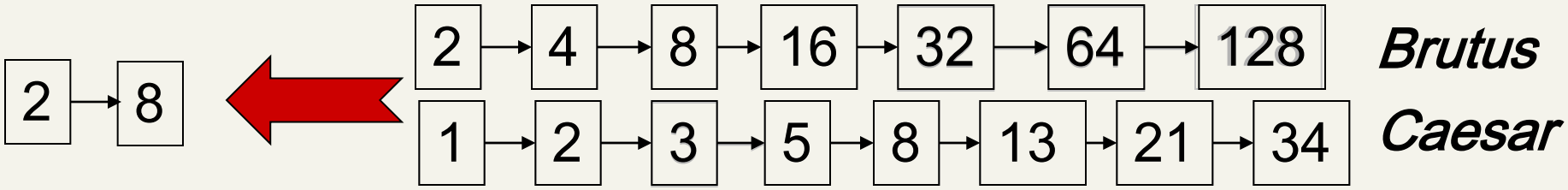
  Brutus** AND **Caesar

  - Locate ***Brutus*** in the Dictionary;
    - Retrieve its postings.
  - Locate *Caesar* in the Dictionary;
    - Retrieve its postings.
  - "Merge" the two postings:



The merge

- Walk through the two postings simultaneously, in time linear in the total number of postings entries



If the list lengths are *x* and *y*, the merge takes O(*x*+*y*) operations.

Crucial: postings sorted by docID.

Intersecting two postings lists (a "merge" algorithm)

```
INTERSECT(p1, p2)
 1  answer ← ⟨ ⟩
 2  while p1 ≠ NIL and p2 ≠ NIL
 3  do if docID(p1) = docID(p2)
 4        then ADD(answer, docID(p1))
 5             p1 ← next(p1)
 6             p2 ← next(p2)
 7        else if docID(p1) < docID(p2)
 8                then p1 ← next(p1)
 9                else p2 ← next(p2)
10  return answer
```

Boolean queries: Exact match

- The Boolean Retrieval model is being able to ask a query that is a Boolean expression:
  - Boolean Queries are queries using *AND, OR* and *NOT* to join query terms
    - Views each document as a set of words
    - Is precise: document matches condition or not.
- Primary commercial retrieval tool for 3 decades.
- Professional searchers (e.g., lawyers) still like Boolean queries:
  - You know exactly what you're getting.

Example: WestLaw http://www.westlaw.com/

- Largest commercial (paying subscribers) legal search service (started 1975; ranking added 1992)
- Tens of terabytes of data; 700,000 users
- Majority of users *still* use boolean queries
- Example query:
  - What is the statute of limitations in cases involving the federal tort claims act?
  - LIMIT! /3 STATUTE ACTION /S FEDERAL /2 TORT /3 CLAIM
- /3 = within 3 words, /S = in same sentence

Example: WestLaw http://www.westlaw.com/

- Another example query:
  - Requirements for disabled people to be able to access a workplace
  - disabl! /p access! /s work-site work-place employment /3 place
- Note that SPACE is disjunction, not conjunction!
- Long, precise queries; proximity operators; incrementally developed; not like web search
- Professional searchers often like Boolean search:
  - Precision, transparency and control
- But that doesn't mean they actually work better….

Boolean queries: More general merges

- Exercise: Adapt the merge for the queries:

  Brutus *AND NOT* ***Caesar***

  Brutus *OR NOT* ***Caesar***

Can we still run through the merge in time O(*x+y*) or what can we achieve?

Merging

What about an arbitrary Boolean formula?

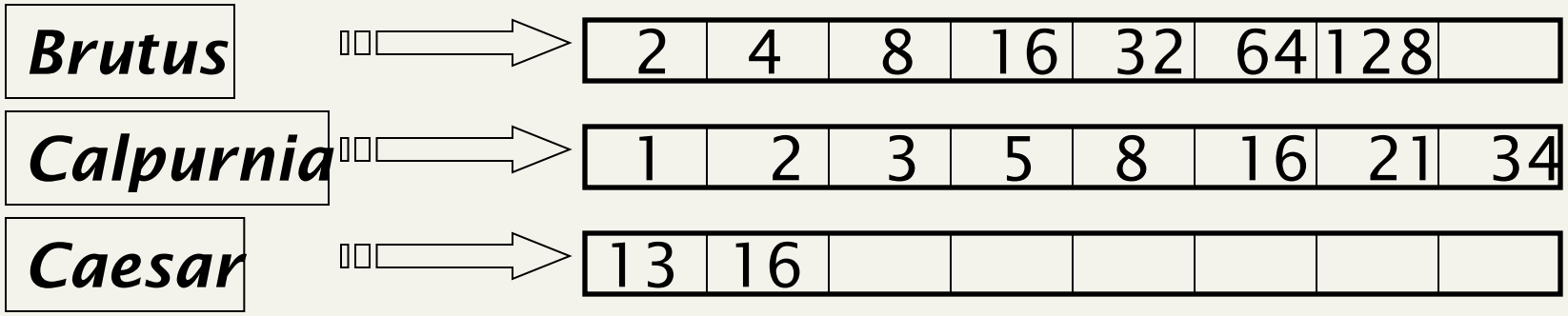
*(**Brutus** OR **Caesar**) AND NOT*

*(**Antony** OR **Cleopatra**)*

- Can we always merge in “linear” time?
  - Linear in what?
- Can we do better?

Query optimization

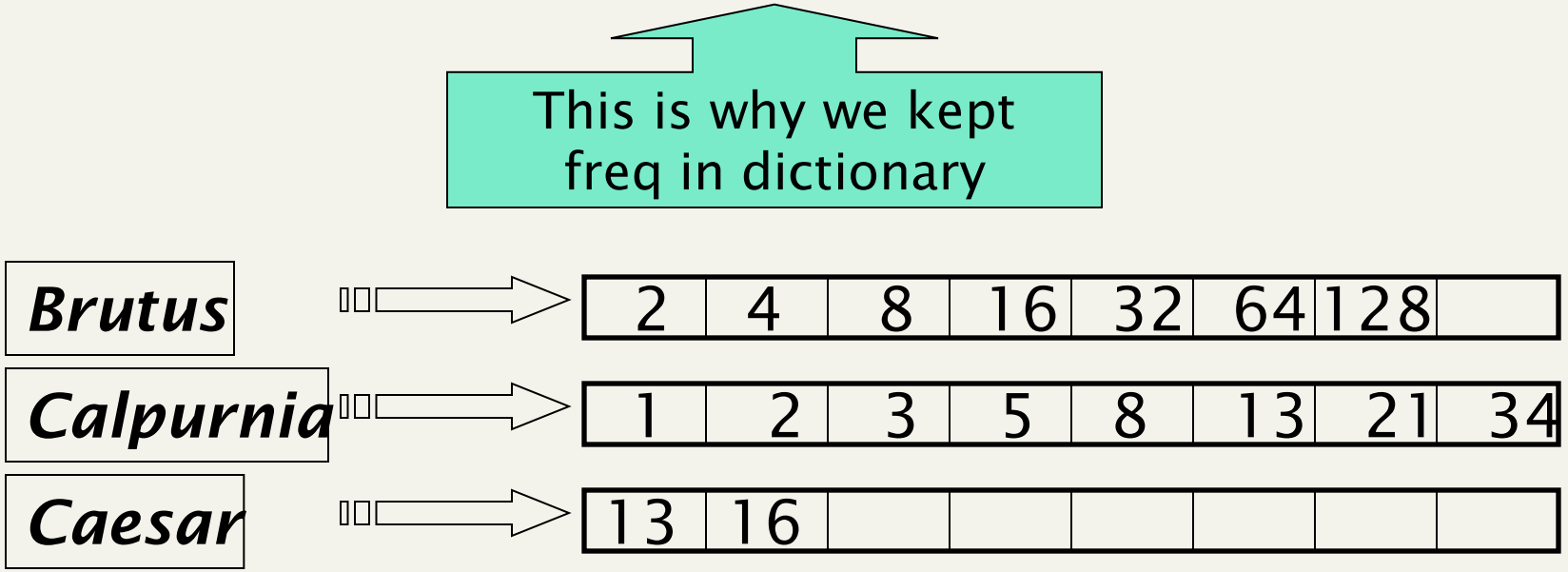
- What is the best order for query processing?
- Consider a query that is an *AND* of *t* terms.
- For each of the *t* terms, get its postings, then *AND* them together.



Query: ***Brutus*** *AND* ***Calpurnia*** *AND* ***Caesar***

Query optimization example

- Process in order of increasing freq:
  - *start with smallest set, then keep cutting further*.



Execute the query as (***Caesar*** *AND* ***Brutus)*** *AND* ***Calpurnia***.

More general optimization

- e.g., *(**madding** OR **crowd**) AND (**ignoble** OR **strife**)*
- Get freq's for all terms.
- Estimate the size of each *OR* by the sum of its freq's (conservative).
- Process in increasing order of *OR* sizes.

Exercise

- Recommend a query processing order for

***(tangerine** OR **trees)** AND*
***(marmalade** OR **skies)** AND*
(kaleidoscope** OR **eyes)

Term	Freq
eyes	213312
kaleidoscope	87009
marmalade	107913
skies	271658
tangerine	46653
trees	316812

Query processing exercises

- If the query is ***friends*** *AND* ***romans*** *AND (NOT* ***countrymen****),* how could we use the freq of ***countrymen***?

Exercise

- Try the search feature at http://www.rhymezone.com/shakespeare/
- Write down five search features you think it could do better

What's ahead in IR? Beyond term search

- What about phrases?
  - ***Stanford University***
- Proximity: Find ***Gates*** *NEAR* ***Microsoft***.
  - Need index to capture position information in docs. More later.
- Zones in documents: Find documents with (*author =* ***Ullman***) *AND* (text contains ***automata***).

Evidence accumulation

- 1 vs. 0 occurrence of a search term
  - 2 vs. 1 occurrence
  - 3 vs. 2 occurrences, etc.
  - Usually more seems better
- Need term frequency information in docs

Ranking search results

- Boolean queries give inclusion or exclusion of docs.
- Often we want to rank/group results
  - Need to measure proximity from query to each doc.
  - Need to decide whether docs presented to user are singletons, or a group of docs covering various aspects of the query.

IR vs. databases: Structured vs unstructured data

- Structured data tends to refer to information in "tables"

Employee	Manager	Salary
Smith	Jones	50000
Chang	Smith	60000
Ivy	Smith	50000

Typically allows numerical range and exact match (for text) queries, e.g.,
Salary < 60000 AND Manager = Smith.

Unstructured data

- Typically refers to free text
- Allows
  - Keyword queries including operators
  - More sophisticated **"concept" queries** e.g.,
    - find all web pages dealing with *drug abuse*
    - Information extraction
- Classic model for searching text documents

Semi-structured data

- In fact almost no data is “unstructured”
- E.g., this slide has distinctly identified zones such as the *Title* and *Bullets*
- Facilitates “semi-structured” search such as
  - *Title* contains data AND *Bullets* contain search

… to say nothing of linguistic structure

More sophisticated semi-structured search

- *Title* is about Object Oriented Programming AND *Author* something like stro*rup
- where * is the wild-card operator
- Issues:
  - how do you process “about”?
  - how do you rank results?
- The focus of XML search.

Clustering vs. Classification

- Given a set of docs, group them into clusters based on their contents.
  - What if not all documents are textual?

- Given a set of topics, plus a new doc *D*, decide which topic(s) *D* belongs to.

More sophisticated *information* retrieval

- Cross-language information retrieval
- Question answering
- Summarization
- Text mining
- …

The web and its challenges

- Unusual and diverse documents
- Unusual and diverse users, queries, information needs
- Beyond terms, exploit ideas from social networks
  - link analysis, clickstreams ...

- How do search engines work? And how can we make them better?

Latest trends in Web IR

- Modeling the role of emotions (using eye tracking and advanced video analyzers)
- Personalization, incl. social network analysis
- Advertising
- Multimedia IR

Resources: The Hadoop Stack

- http://hadoop.apache.org/
  - **HDFS** (Hadoop Distributed File System)
    - Replication
    - Data locality – based on the location of the replicas
    - http://pages.cs.wisc.edu/~remzi/Classes/736/Spring2008/Papers/gfs-sosp2003.pdf
  - **MapReduce** (more on this later)
    - http://cs.gmu.edu/~astavrou/courses/CS_571_F09/mapreduce-osdi04.pdf

Resources: The Hadoop Stack (cont.)

- **HBase**: http://hbase.apache.org/
  - Distributed database on top of HDFS
  - Map-Reduce enabled
  - Fault-tolerant and scalable
  - http://labs.google.com/papers/bigtable-osdi06.pdf
- **Mahout**: http://mahout.apache.org/
  - Machine learning and Data mining on top of Hadoop
- **ZooKeeper**: http://zookeeper.apache.org/
  - Coordination service

Resources: The Hadoop Stack (cont.)

- **Hive**: http://hive.apache.org/
  - Data warehousing + Summarization / Analytics / etc.
  - SQL-like query language
- **Pig**: http://pig.apache.org/
  - Parallelization component
- **Avro**: http://avro.apache.org/
  - Data serialization

Resources: The H-Stack Competition

- **Cassandra**: http://cassandra.apache.org/
  - http://www.allthingsdistributed.com/files/amazon-dynamo-sosp2007.pdf
- **Mongo DB**: http://www.mongodb.org/
- **Couch DB** (not): http://couchdb.apache.org/

- See a comparison here:
  - http://kkovacs.eu/cassandra-vs-mongodb-vs-couchdb-vs-redis

Resources: Other

- Google Talk at last year's IAB MIXX conference
  - http://www.google.com/adwords/watchthisspace/live/

Presentation Skills

(to be used for your group research project)

Principles: Preparation

- Research your audience
  - Background / Technicality level
  - What can I do to make this useful for them?
- Plan your presentation
  - Define your goals
    - What do I want my audience to KNOW, FEEL, and DO (KFD) once they leave the room?
  - Gather information / Research your topic
  - Create an outline

Principles: Slides

- In general, they should be a **companion** to what you are saying
  - For academic courses, you want the content to be accessible later as well, so compromise on this
- Make sure you follow the 3 phase approach
  - What will you cover & Why: 1-2 slides
  - Bulk of the slides
  - What have you covered & **Which is the take away**

Principles: Slides (cont.)

- 5 x 5 rule: 5 bullets x 5 words
  - Use 2 colors to enhance text, possibly also bold
  - Add some memorable images to this
- You may want to add slide notes to help you
  - Think about a great introduction
    - http://www.youtube.com/watch?v=wvsboPUjrGc
- For your 50 min. talk, you should prepare 20-40 slides.

Principles: Talk

- Rehearsal
  - Rehearse **at least once** before coming to class
  - Make sure you will finish on time (have intermediary checkpoints to help you on that)
  - Make sure you will say all you wanted to say
- Delivery
  - Keep eye contact with the audience
  - Ask questions / Wake them up if needed :D

What NOT to do

- Very well summarized in Life After Death by PowerPoint
  - http://www.youtube.com/watch?v=KbSPPFYxx3o
  - Please respect these principles ;-)