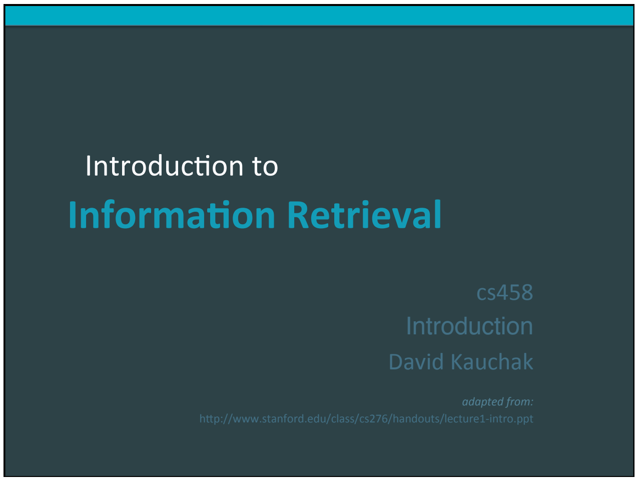


Introduction to

Information Retrieval

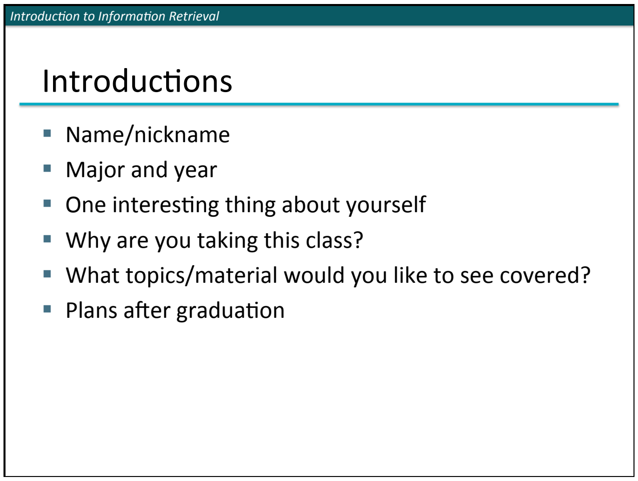
cs458

Introduction

David Kauchak

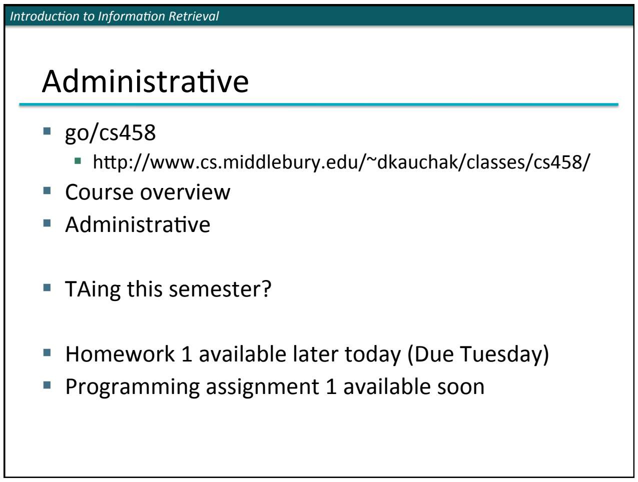
adapted from:

http://www.stanford.edu/class/cs276/handouts/lecture1-intro.ppt



Introductions

- Name/nickname
- Major and year
- One interesting thing about yourself
- Why are you taking this class?
- What topics/material would you like to see covered?
- Plans after graduation

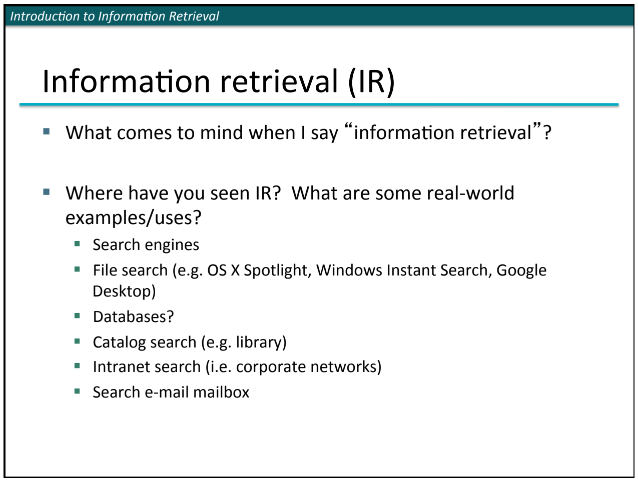


Administrative

- go/cs458
  - http://www.cs.middlebury.edu/~dkauchak/classes/cs458/
- Course overview
- Administrative

- TAing this semester?

- Homework 1 available later today (Due Tuesday)
- Programming assignment 1 available soon



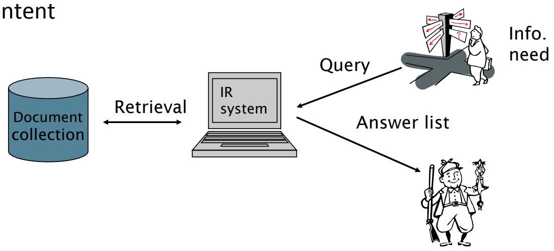
Information retrieval (IR)

- What comes to mind when I say “information retrieval”?

- Where have you seen IR? What are some real-world examples/uses?
  - Search engines
  - File search (e.g. OS X Spotlight, Windows Instant Search, Google Desktop)
  - Databases?
  - Catalog search (e.g. library)
  - Intranet search (i.e. corporate networks)
  - Search e-mail mailbox

Information Retrieval

Information Retrieval is finding material in documents of an unstructured nature that satisfy an information need from within large collections of digitally stored content



Information Retrieval

Information Retrieval is finding material in documents of an unstructured nature that satisfy an information need from within large collections of digitally stored content

?

Dictionary says…

- Oxford English Dictionary

  information: informing, telling; thing told, knowledge, items of knowledge, news

- Random House Dictionary

  information: knowledge communicated or received concerning a particular fact or circumstance; news

Information Retrieval

Information Retrieval is finding material in documents of an unstructured nature that satisfy an information need from within large collections of digitally stored content

- Find all documents about computer science
- Find all course web pages at Middlebury
- What is the cheapest flight from LA to NY?
- Who is was the 15th president?

Information Retrieval

Information Retrieval is finding material in documents of an unstructured nature that satisfy an information need from within large collections of digitally stored content

What is the difference between an *information need* and a *query?*

Information Retrieval

Information Retrieval is finding material in documents of an unstructured nature that satisfy an information need from within large collections of digitally stored content

Information need	Query
· Find all documents about computer science	"computer science"
· Find all course web pages at Pomona	Pomona AND college AND *url-contains* class
· Who is was the 15th president?	WHO=president NUMBER=15

Challenges

Why is information retrieval hard?

- Lots and lots of data
  - efficiency
  - storage
  - discovery (web)
- Data is unstructured
- Querying/Understanding user intent
- SPAM
- Data quality

web search engine traffic

About 92,200,000 results (0.13 seconds)

Challenges

Why is information retrieval hard?

- Lots and lots of data
  - efficiency
  - storage
  - discovery (web)
- Data is unstructured
- Understanding user intent
- SPAM
- Data quality

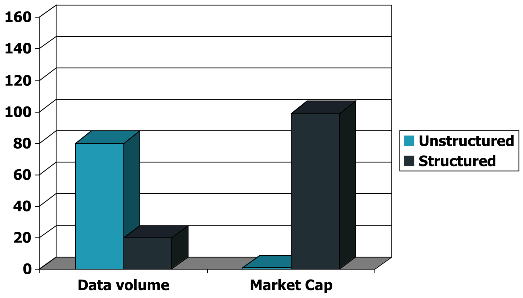
IR vs. databases

Structured data tends to refer to information in “tables”

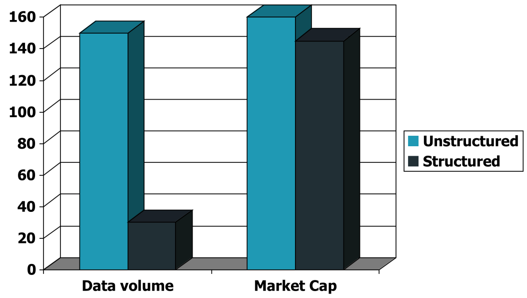
Employee	Manager	Salary
Smith	Jones	50000
Chang	Smith	60000
Ivy	Smith	50000

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

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



Unstructured (text) vs. structured (database) data in 2006



Challenges

Why is information retrieval hard?

- Lots and lots of data
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  - storage
  - discovery (web)
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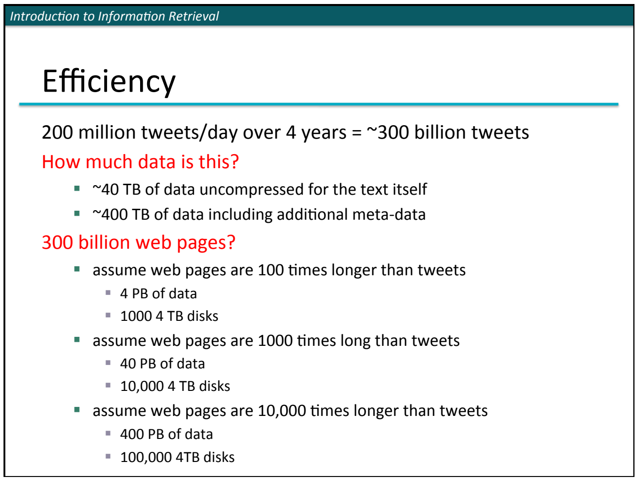
- Data quality



Efficiency

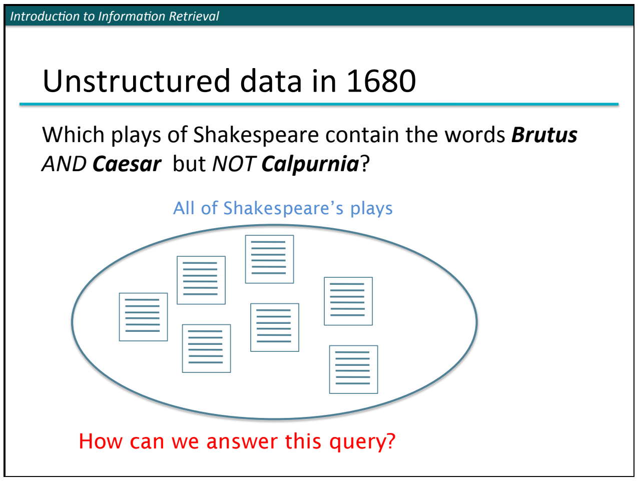
200 million tweets/day over 4 years = ~300 billion tweets

How much data is this?

- ~40 TB of data uncompressed for the text itself
- ~400 TB of data including additional meta-data

300 billion web pages?

- assume web pages are 100 times longer than tweets
  - 4 PB of data
  - 1000 4 TB disks
- assume web pages are 1000 times long than tweets
  - 40 PB of data
  - 10,000 4 TB disks
- assume web pages are 10,000 times longer than tweets
  - 400 PB of data
  - 100,000 4TB disks

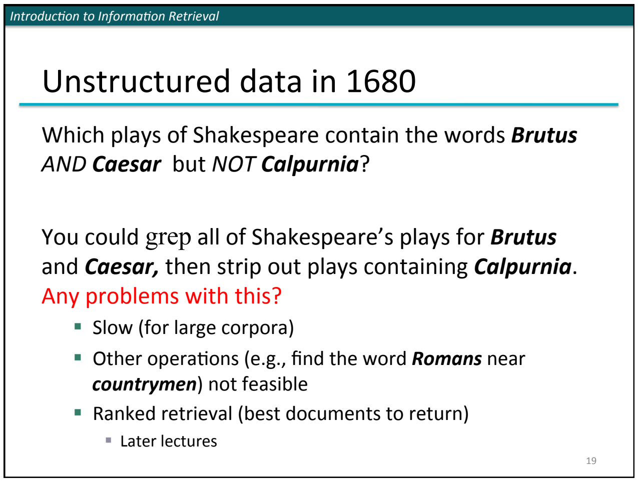


Unstructured data in 1680

Which plays of Shakespeare contain the words ***Brutus*** *AND* ***Caesar*** but *NOT* ***Calpurnia***?

All of Shakespeare's plays

How can we answer this query?



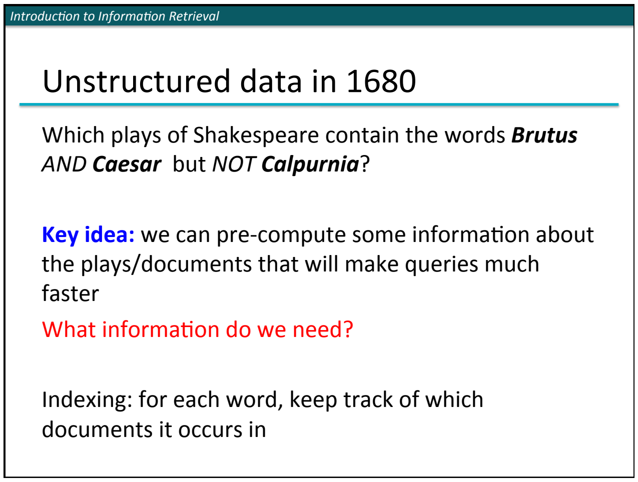
Unstructured data in 1680

Which plays of Shakespeare contain the words ***Brutus*** *AND* ***Caesar*** but *NOT* ***Calpurnia***?

You could grep all of Shakespeare's plays for ***Brutus*** and ***Caesar,*** then strip out plays containing ***Calpurnia***.

Any problems with this?

- Slow (for large corpora)
- Other operations (e.g., find the word ***Romans*** near ***countrymen***) not feasible
- Ranked retrieval (best documents to return)
  - Later lectures



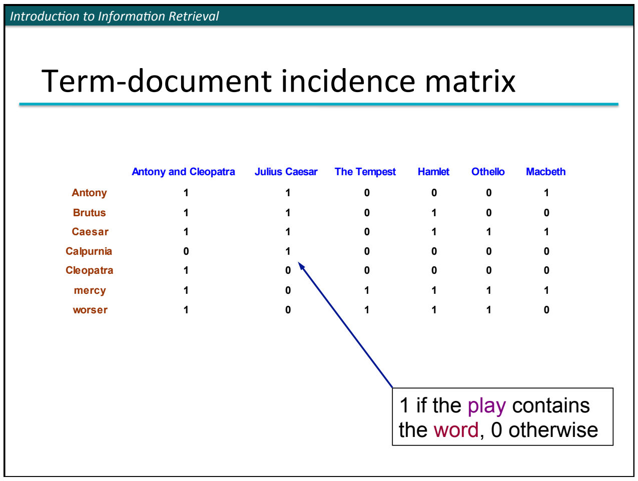
Unstructured data in 1680

Which plays of Shakespeare contain the words ***Brutus*** *AND* ***Caesar*** but *NOT* ***Calpurnia***?

Key idea: we can pre-compute some information about the plays/documents that will make queries much faster

What information do we need?

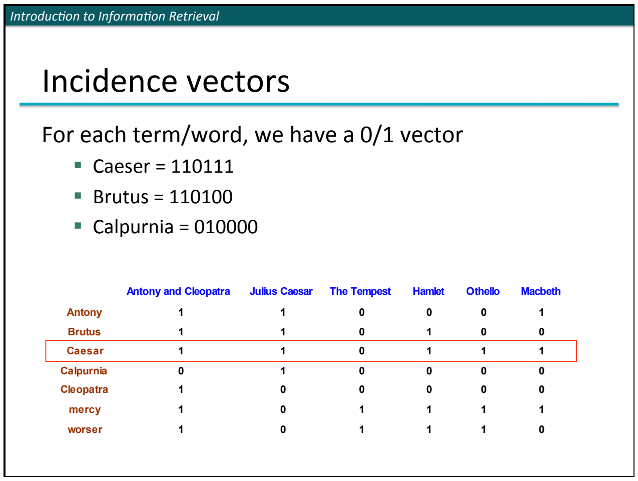
Indexing: for each word, keep track of which documents it occurs in



Term-document incidence matrix

	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 the play contains the word, 0 otherwise



Incidence vectors

For each term/word, we have a 0/1 vector

- Caeser = 110111
- Brutus = 110100
- Calpurnia = 010000

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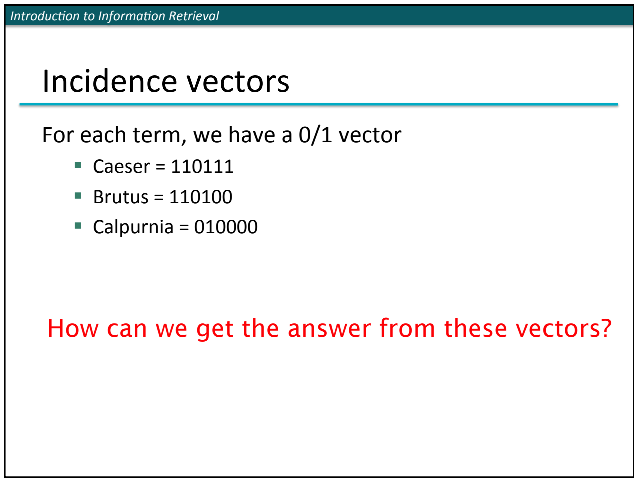
Caesar	1	1	0	1	1	1
Calpurnia	0	1	0	0	0	0
Cleopatra	1	0	0	0	0	0
mercy	1	0	1	1	1	1
worser	1	0	1	1	1	0

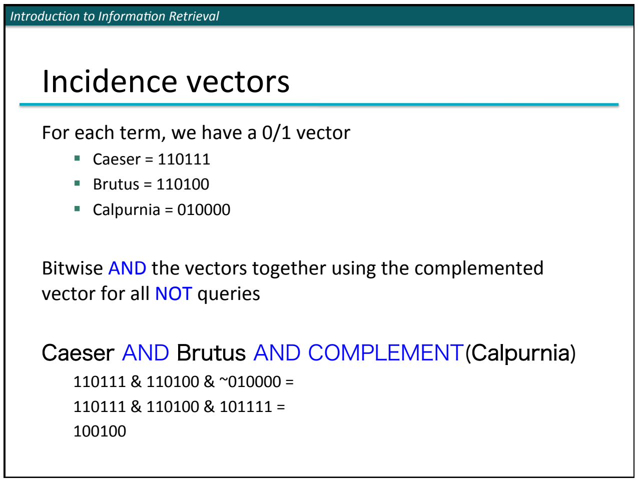


Incidence vectors

For each term, we have a 0/1 vector

- Caeser = 110111
- Brutus = 110100
- Calpurnia = 010000

How can we get the answer from these vectors?



Incidence vectors

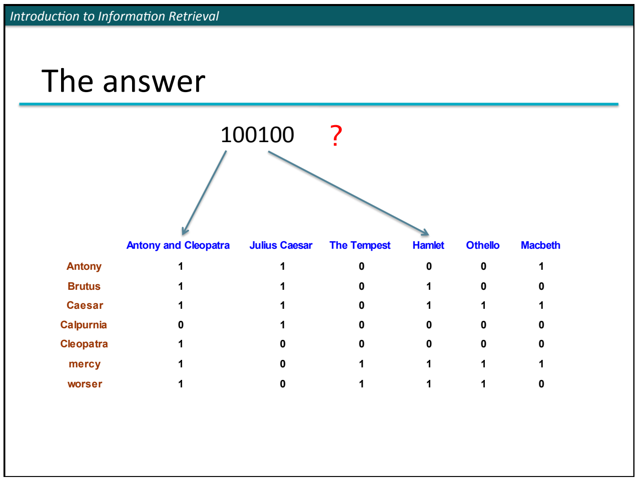
For each term, we have a 0/1 vector

- Caeser = 110111
- Brutus = 110100
- Calpurnia = 010000

Bitwise AND the vectors together using the complemented vector for all NOT queries

Caeser AND Brutus AND COMPLEMENT(Calpurnia)

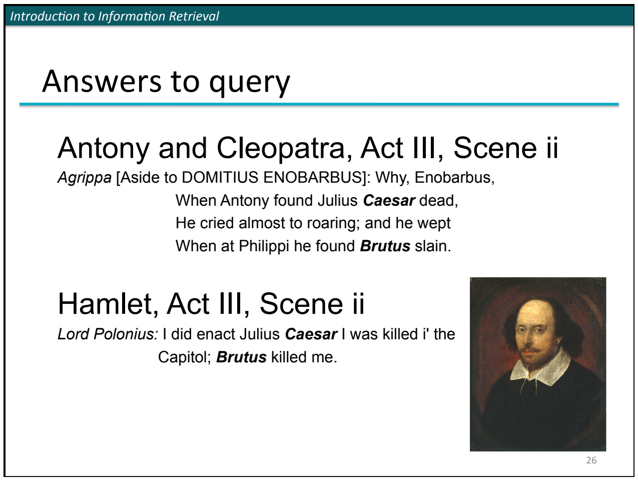
110111 & 110100 & ~010000 =
110111 & 110100 & 101111 =
100100



The answer

100100 ?

	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



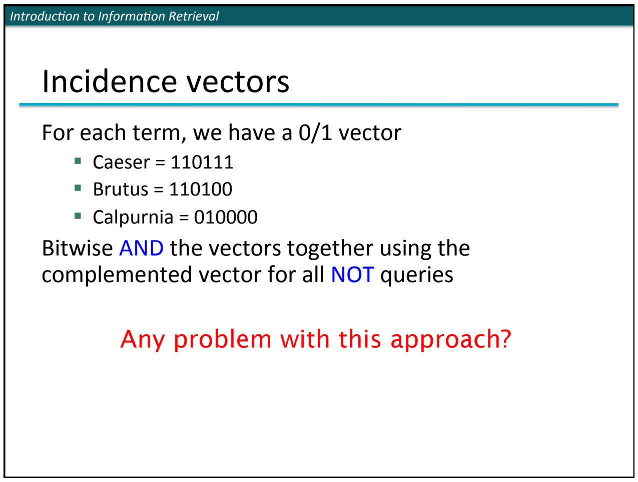
Answers to query

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.



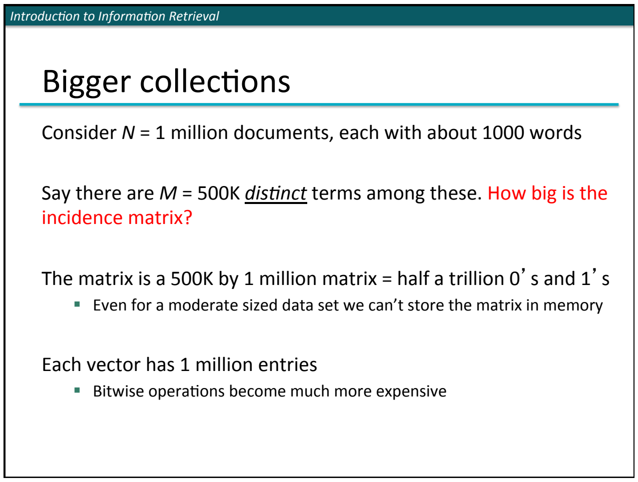
Incidence vectors

For each term, we have a 0/1 vector

- Caeser = 110111
- Brutus = 110100
- Calpurnia = 010000

Bitwise AND the vectors together using the complemented vector for all NOT queries

Any problem with this approach?



Bigger collections

Consider *N* = 1 million documents, each with about 1000 words

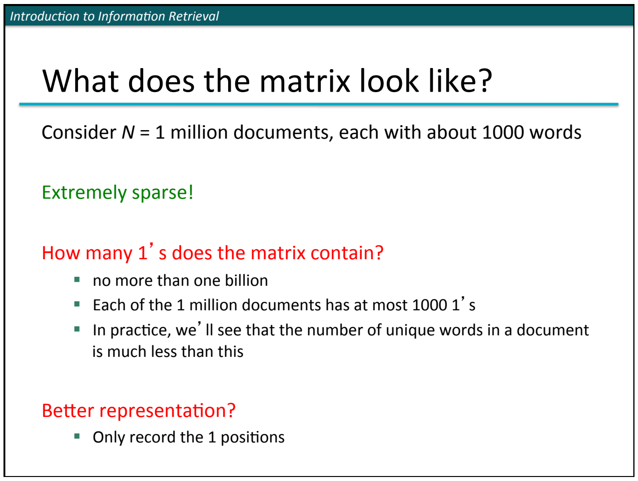
Say there are *M* = 500K *distinct* terms among these. How big is the incidence matrix?

The matrix is a 500K by 1 million matrix = half a trillion 0's and 1's

- Even for a moderate sized data set we can't store the matrix in memory

Each vector has 1 million entries

- Bitwise operations become much more expensive



What does the matrix look like?

Consider *N* = 1 million documents, each with about 1000 words

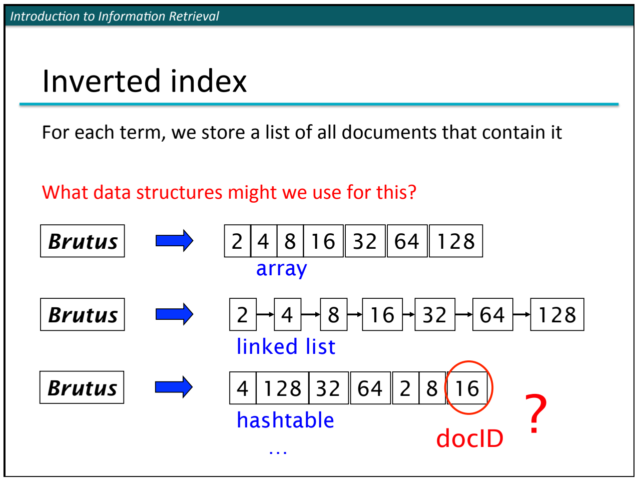
Extremely sparse!

How many 1’ s does the matrix contain?

- no more than one billion
- Each of the 1 million documents has at most 1000 1’ s
- In practice, we’ ll see that the number of unique words in a document is much less than this

Better representation?

- Only record the 1 positions



Inverted index

For each term, we store a list of all documents that contain it

What data structures might we use for this?

Brutus → 2 | 4 | 8 | 16 | 32 | 64 | 128

array

Brutus → 2 → 4 → 8 → 16 → 32 → 64 → 128

linked list

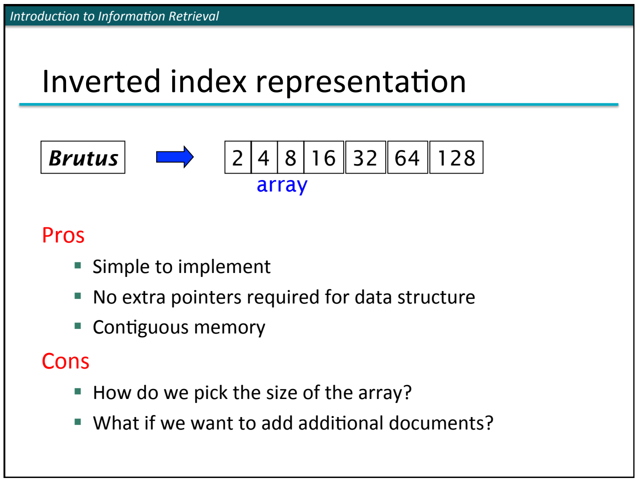
Brutus → 4 | 128 | 32 | 64 | 2 | 8 | 16

hashtable

…

docID

?



Inverted index representation

Brutus → 2 | 4 | 8 | 16 | 32 | 64 | 128

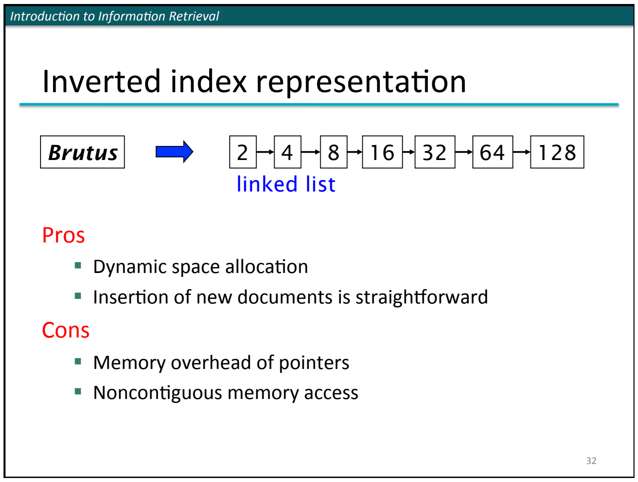
array

Pros

- Simple to implement
- No extra pointers required for data structure
- Contiguous memory

Cons

- How do we pick the size of the array?
- What if we want to add additional documents?



Inverted index representation

Brutus → 2 → 4 → 8 → 16 → 32 → 64 → 128

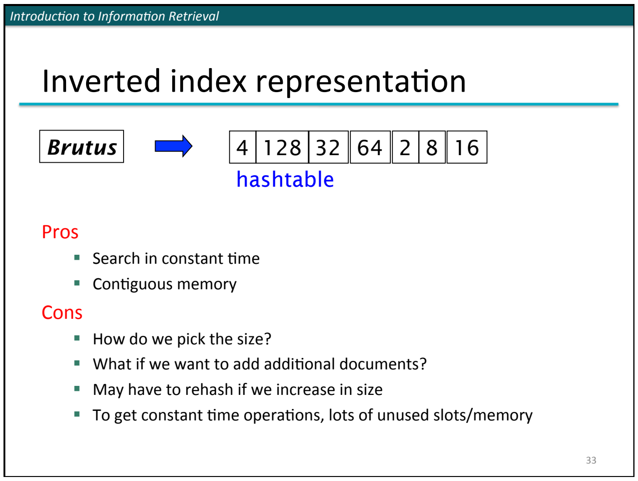
linked list

Pros

- Dynamic space allocation
- Insertion of new documents is straightforward

Cons

- Memory overhead of pointers
- Noncontiguous memory access



Inverted index representation

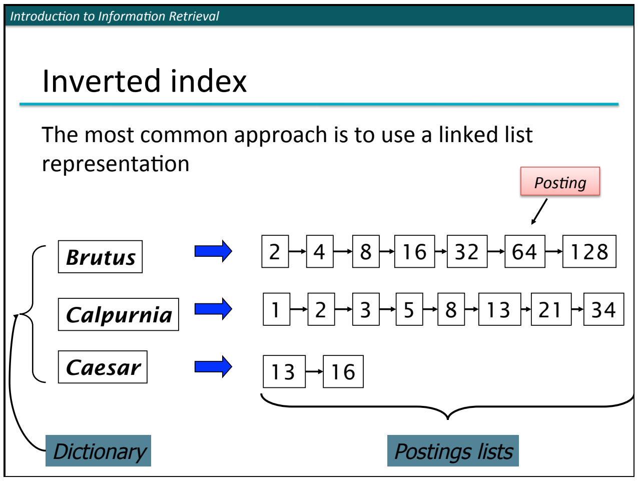
Brutus
4 | 128 | 32 | 64 | 2 | 8 | 16
hashtable

Pros

- Search in constant time
- Contiguous memory

Cons

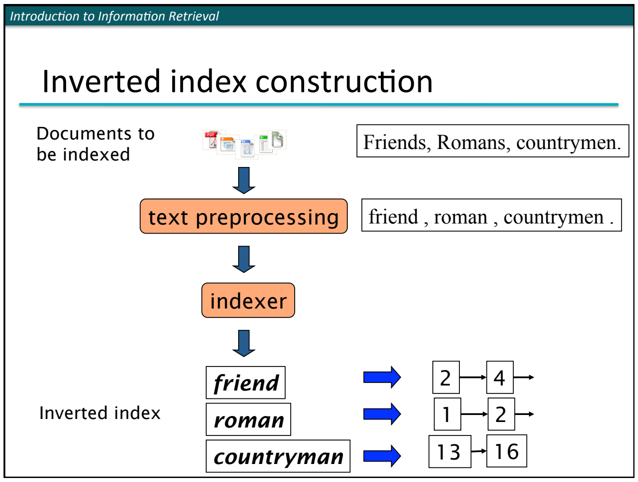
- How do we pick the size?
- What if we want to add additional documents?
- May have to rehash if we increase in size
- To get constant time operations, lots of unused slots/memory



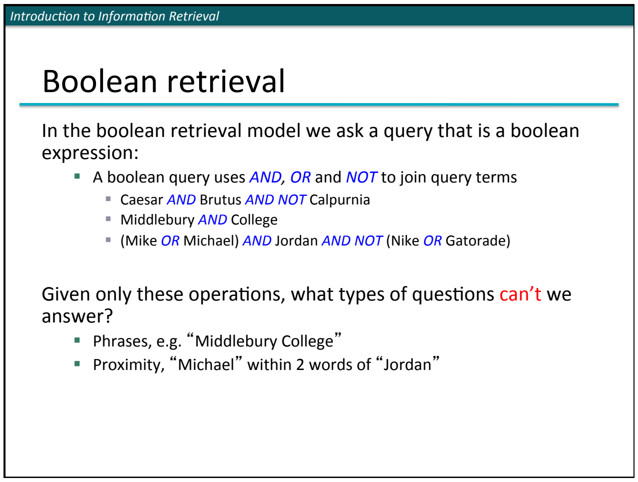
Inverted index

The most common approach is to use a linked list representation

Posting
Brutus → 2 → 4 → 8 → 16 → 32 → 64 → 128
Calpurnia → 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34
Caesar → 13 → 16
Dictionary
Postings lists



Inverted index construction



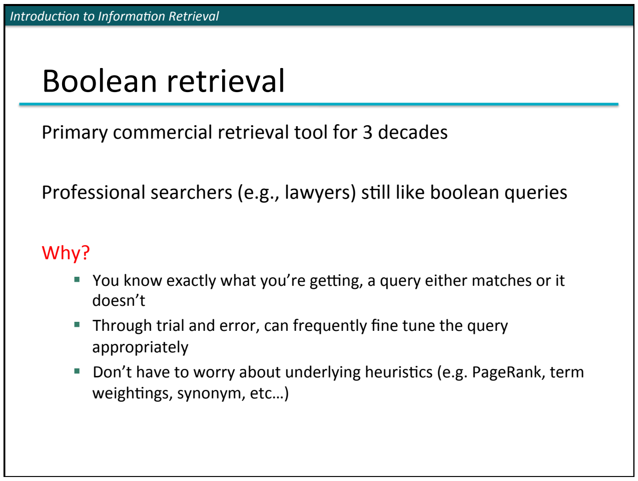
Boolean retrieval

In the boolean retrieval model we ask a query that is a boolean expression:

- A boolean query uses *AND, OR* and *NOT* to join query terms
  - Caesar *AND* Brutus *AND NOT* Calpurnia
  - Middlebury *AND* College
  - (Mike *OR* Michael) *AND* Jordan *AND NOT* (Nike *OR* Gatorade)

Given only these operations, what types of questions can't we answer?

- Phrases, e.g. "Middlebury College"
- Proximity, "Michael" within 2 words of "Jordan"



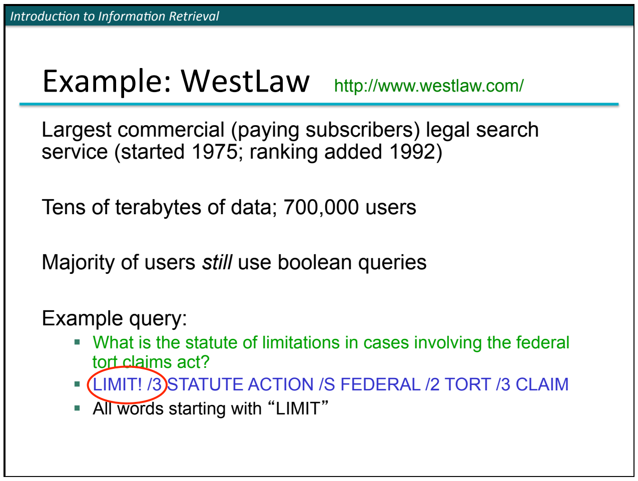
Boolean retrieval

Primary commercial retrieval tool for 3 decades

Professional searchers (e.g., lawyers) still like boolean queries

Why?

- You know exactly what you're getting, a query either matches or it doesn't
- Through trial and error, can frequently fine tune the query appropriately
- Don't have to worry about underlying heuristics (e.g. PageRank, term weightings, synonym, etc…)



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

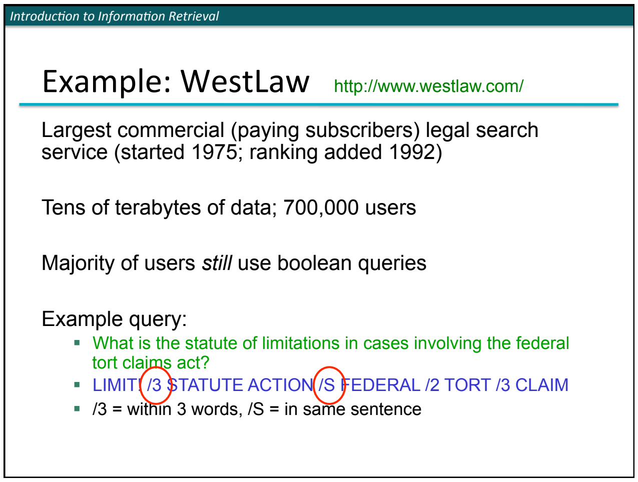
Largest commercial (paying subscribers) legal search service (started 1975; ranking added 1992)

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
- All words starting with "LIMIT"



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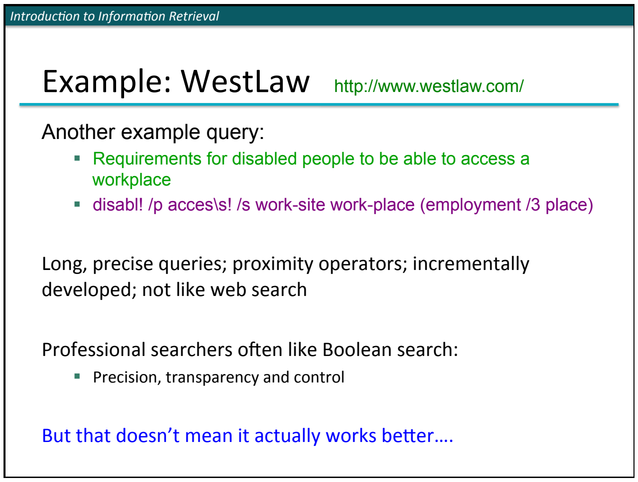
Majority of users *still* use boolean queries

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:

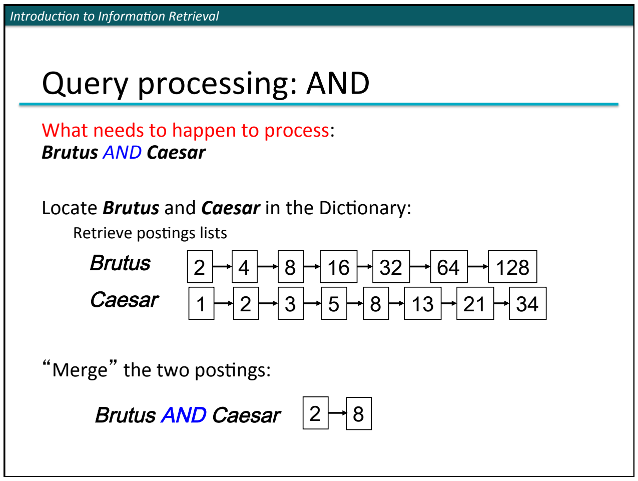
- Requirements for disabled people to be able to access a workplace
- disabl! /p acces\s! /s work-site work-place (employment /3 place)

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 it actually works better….



Query processing: AND

What needs to happen to process:
Brutus *AND* ***Caesar***

Locate ***Brutus*** and ***Caesar*** in the Dictionary:

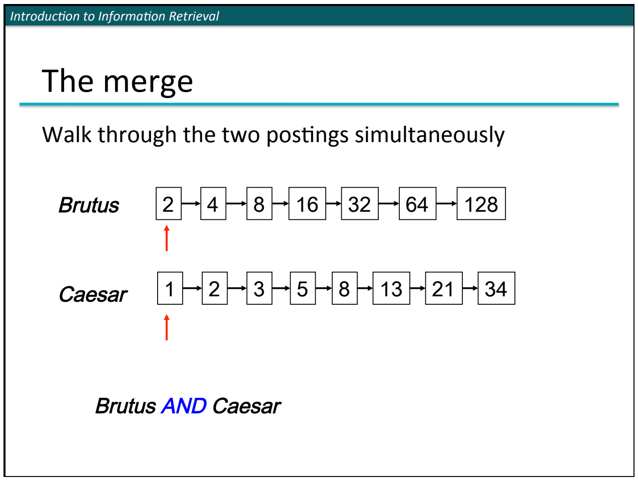
- Retrieve postings lists

Brutus 2 → 4 → 8 → 16 → 32 → 64 → 128

Caesar 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34

"Merge" the two postings:

Brutus AND Caesar 2 → 8



The merge

Walk through the two postings simultaneously

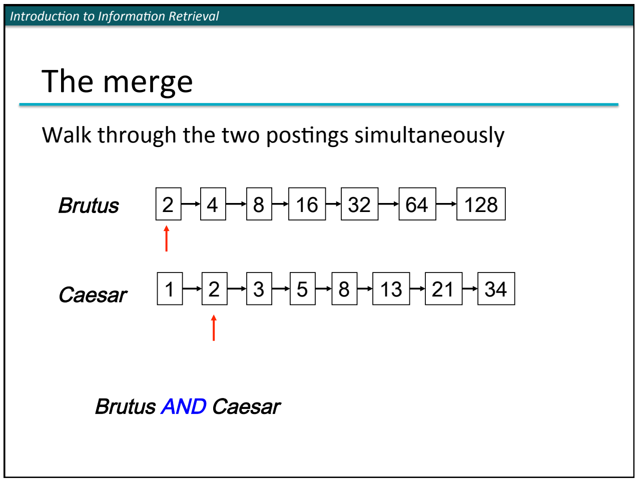
Brutus 2 → 4 → 8 → 16 → 32 → 64 → 128

↑

Caesar 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34

↑

Brutus AND Caesar



The merge

Walk through the two postings simultaneously

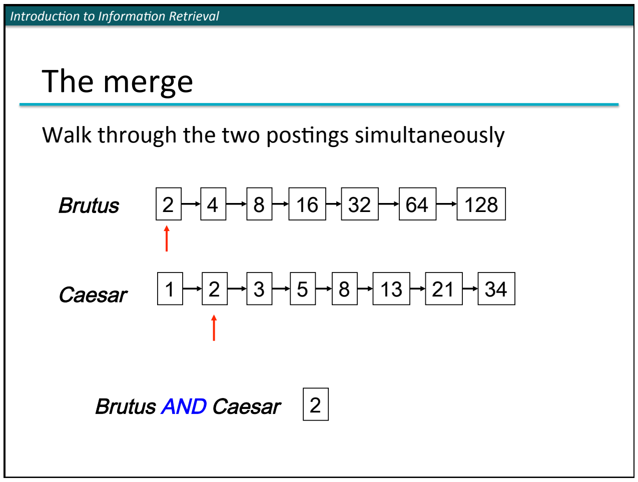
Brutus 2 → 4 → 8 → 16 → 32 → 64 → 128

↑

Caesar 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34

↑

Brutus AND Caesar



The merge

Walk through the two postings simultaneously

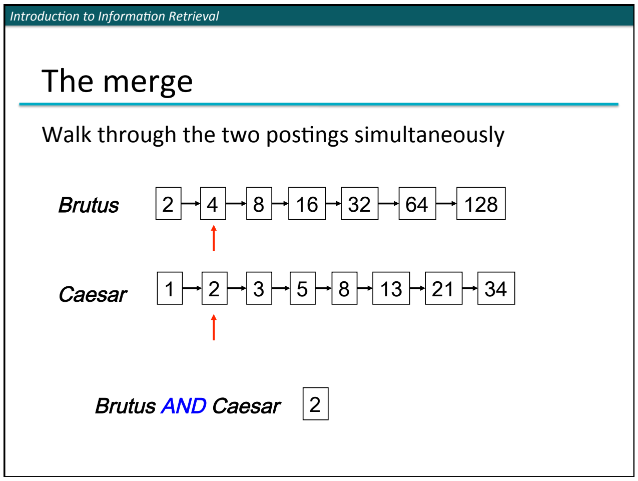
Brutus 2 → 4 → 8 → 16 → 32 → 64 → 128

↑

Caesar 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34

↑

Brutus AND Caesar 2



The merge

Walk through the two postings simultaneously

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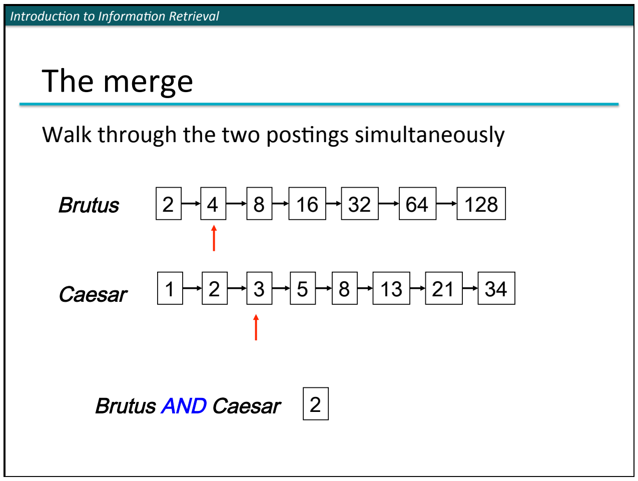
↑

Caesar 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34

↑

Brutus AND Caesar 2



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Walk through the two postings simultaneously

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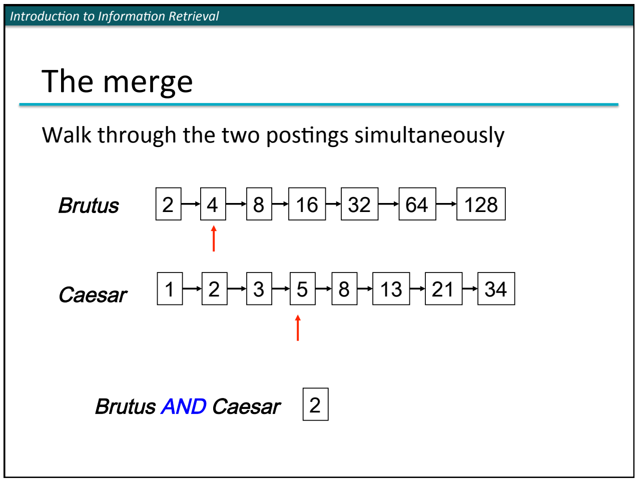
Caesar 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34

↑

Brutus AND Caesar 2



The merge

Walk through the two postings simultaneously

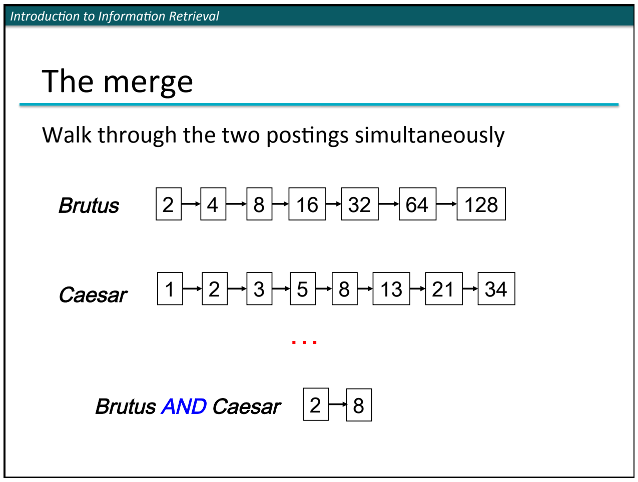
Brutus 2 → 4 → 8 → 16 → 32 → 64 → 128

↑

Caesar 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34

↑

Brutus AND Caesar 2



The merge

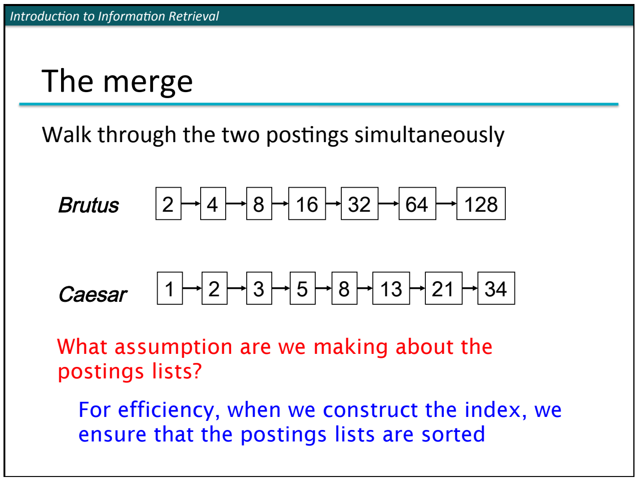
Walk through the two postings simultaneously

Brutus 2 → 4 → 8 → 16 → 32 → 64 → 128

Caesar 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34

. . .

Brutus AND Caesar 2 → 8



The merge

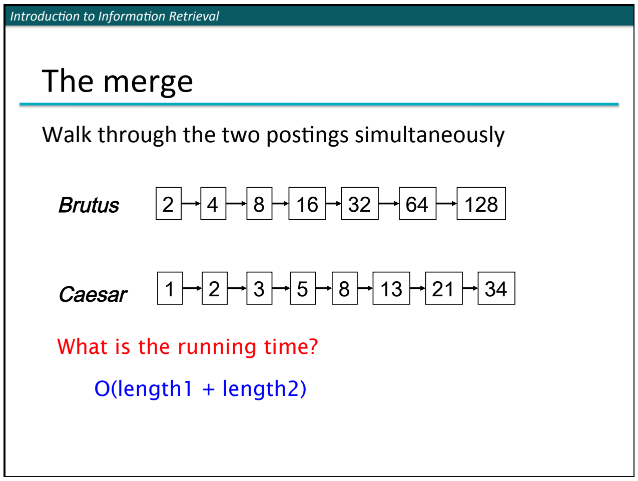
Walk through the two postings simultaneously

Brutus 2 → 4 → 8 → 16 → 32 → 64 → 128

Caesar 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34

What assumption are we making about the postings lists?

For efficiency, when we construct the index, we ensure that the postings lists are sorted



The merge

Walk through the two postings simultaneously

Brutus 2 → 4 → 8 → 16 → 32 → 64 → 128

Caesar 1 → 2 → 3 → 5 → 8 → 13 → 21 → 34

What is the running time?

O(length1 + length2)