Boolean Retrieval[1]

September, 2009

[1] Vorlage: Folien von M. Schütze zu [1]

Boolean Retrieval

- Fragen sind Boolesche Ausdrücke, z.B.: Caesar AND Brutus
- Die Suchmaschine gibt **alle** Dokumente zurück, die der Anfrage entsprechen.

Does Google use the Boolean model?

Outline

Unstructured data in 1650

- 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.
- Why is grep not the solution?

Unstructured data in 1650

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- One could grep all of Shakespeare's plays for Brutus and Caesar, then strip out lines containing Calpurnia.
- Why is grep not the solution?
  - Slow (for large collections)
  - " NOT Calpurnia" is non-trivial
  - Other operations (e.g., find the word Romans near countryman) not feasible
  - Ranked retrieval (best documents to return) – focus of later lectures, but not this one

Term-document incidence matrix

	Anthony and Cleopatra	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth	...
Anthony	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	

...

Entry is 1 if term occurs. Example: Calpurnia occurs in Julius Caesar.
Entry is 0 if term doesn't occur. Example: Calpurnia doesn't occur in The tempest.

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- To answer the query Brutus AND Caesar AND NOT Calpurnia:
  - Take the vectors for Brutus, Caesar, and Calpurnia
  - Complement the vector of Calpurnia
  - Do a (bitwise) AND on the three vectors
  - 110100 AND 110111 AND 101111 = 100100

0/1 vector for Brutus

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worser	1	0	1	1	1	0	
...							

Answers to query

Anthony 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.

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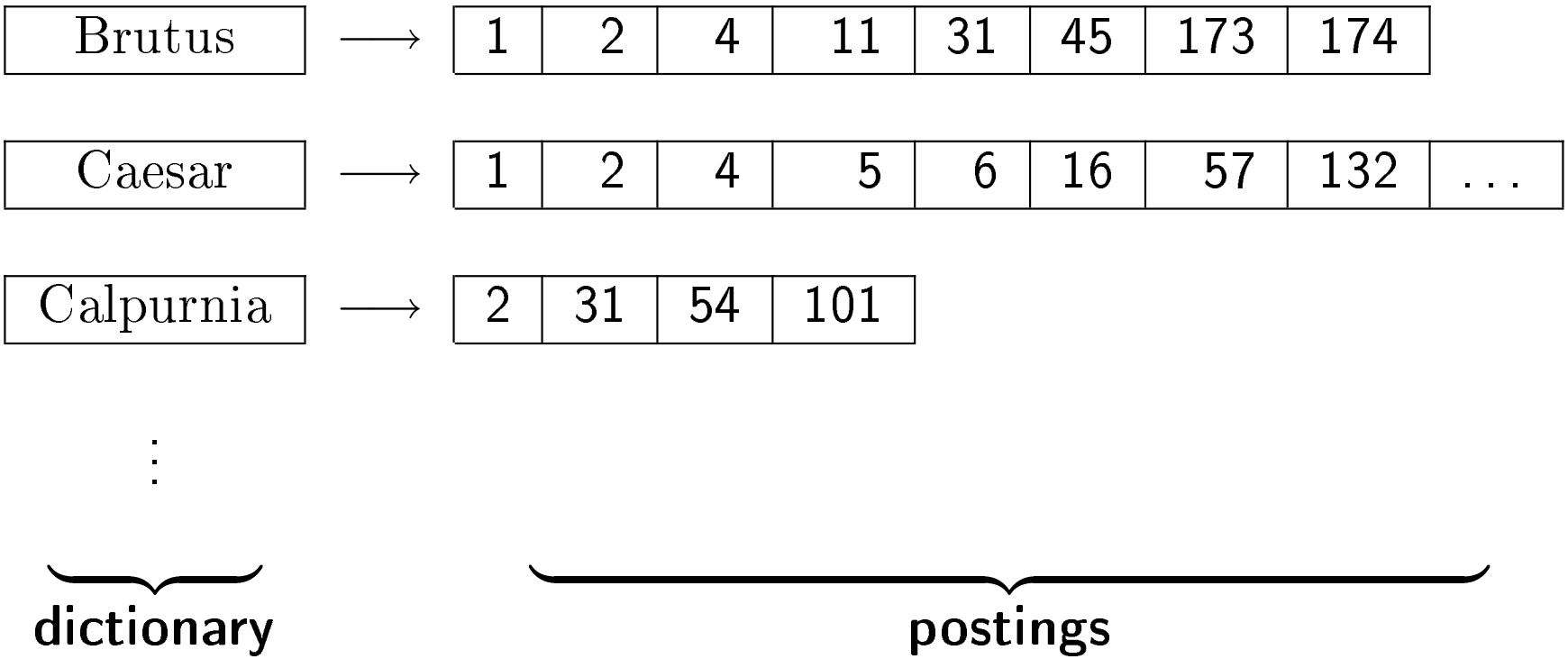
- (Notice that we are making a term/token distinction.)

Can't build the incidence matrix

- $M = 500{,}000 \times 10^6 =$ half a trillion 0s and 1s.
- But the matrix has no more than one billion 1s.
  - Matrix is extremely sparse.
- What is a better representations?
  - We only record the 1s.

Inverted Index

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



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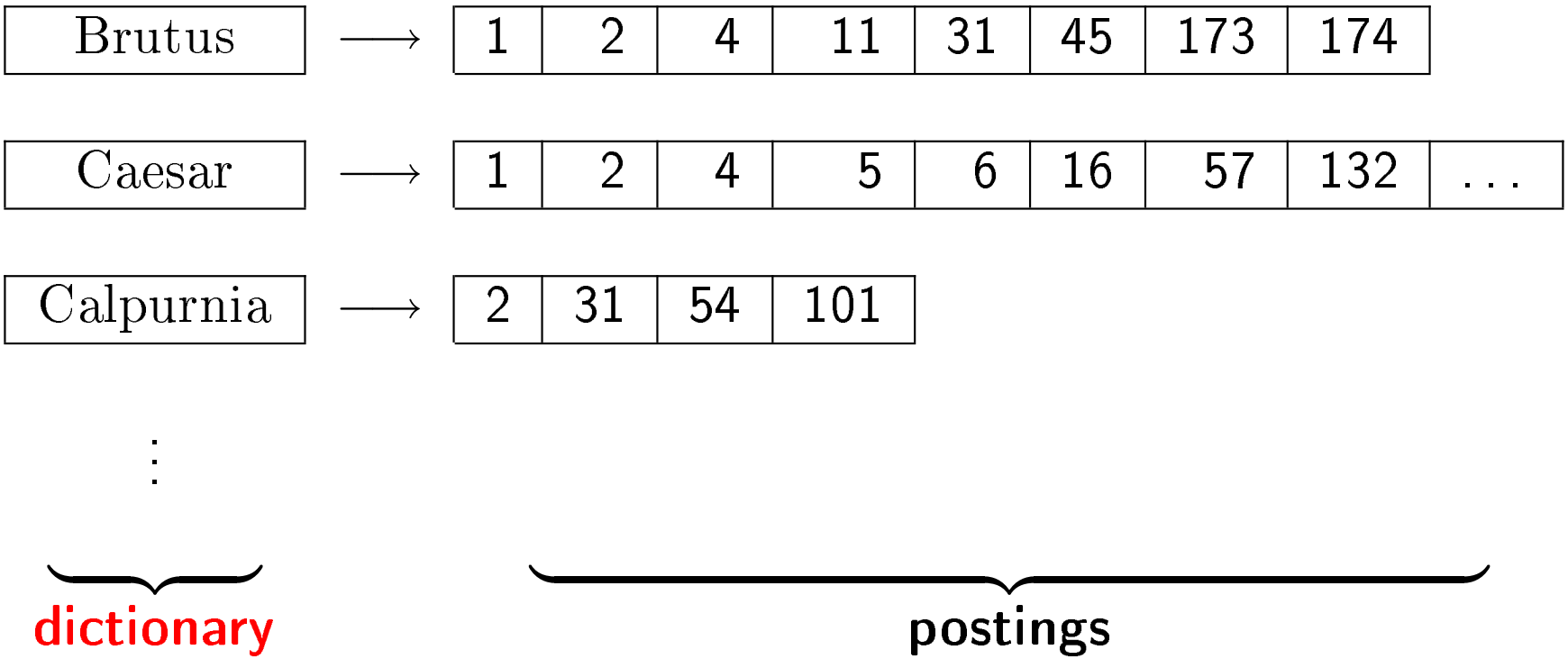

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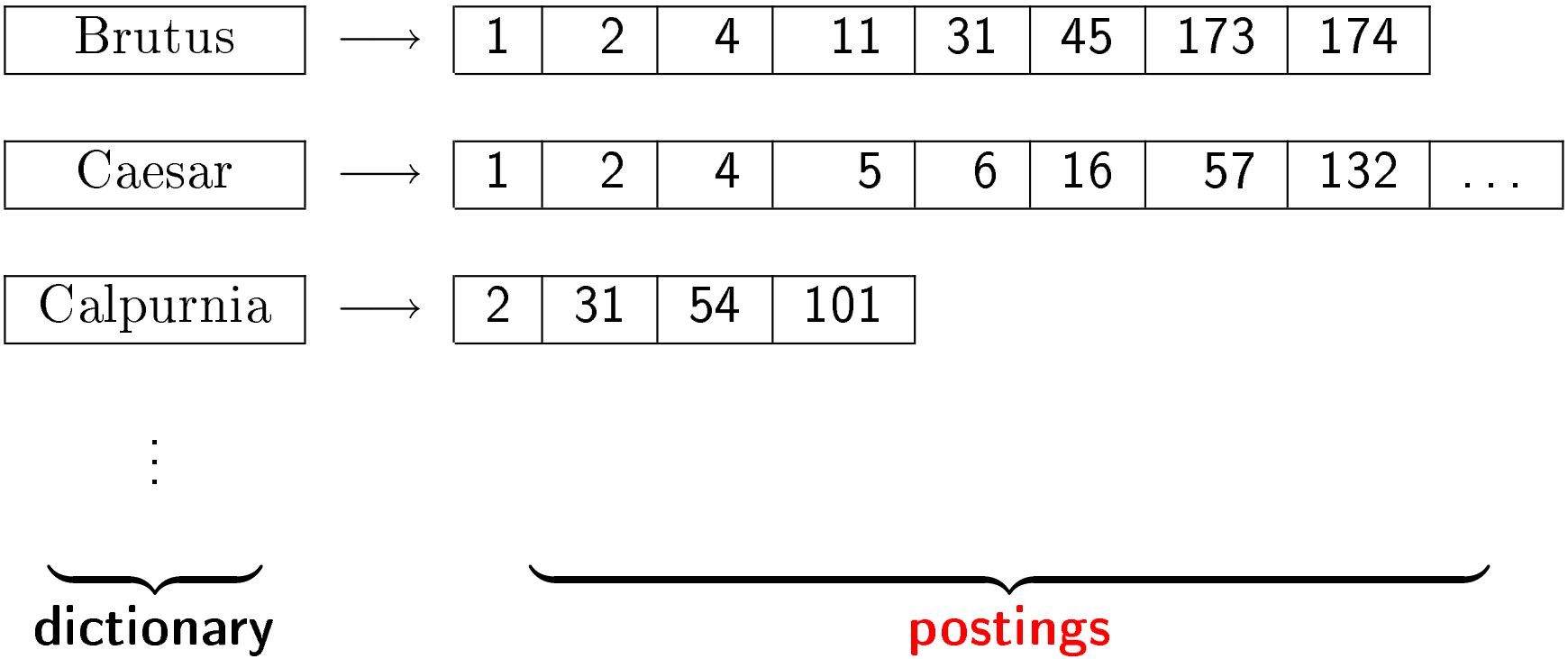

Inverted index construction

1. Collect the documents to be indexed:
   Friends, Romans, countrymen. | So let it be with Caesar
   ...
2. Tokenize the text, turning each document into a list of tokens:
   Friends | Romans | countrymen | So ...
3. Do linguistic preprocessing, producing a list of normalized tokens, which are the indexing terms: friend | roman | countryman | so ...
4. Index the documents that each term occurs in by creating an inverted index, consisting of a dictionary and postings.

Tokenization and preprocessing

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:

$\Longrightarrow$

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

Generate postings

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

$\Longrightarrow$

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

Sort postings

term	docID
I	1
did	1
enact	1
julius	1
caesar	1
I	1
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i'	1
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capitol	1
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so	2
let	2
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be	2
with	2
caesar	2
the	2
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caesar	2
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ambitious	2
be	2
brutus	1
brutus	2
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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

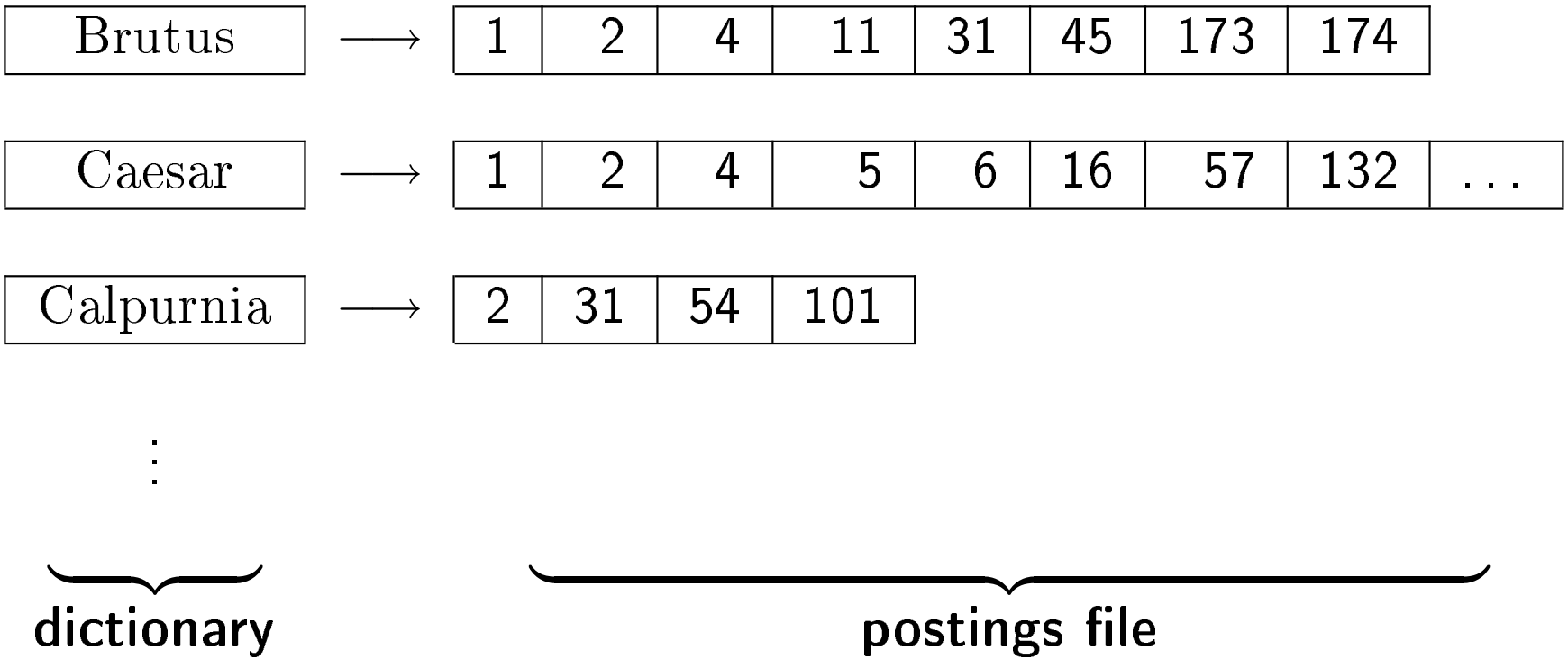
Create postings lists, determine document frequency

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

Split the result into dictionary and postings file



Outline

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  3. Locate Calpurnia in the dictionary

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  1. Locate Brutus in the dictionary
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  4. Retrieve its postings list from the postings file
  5. Intersect the two postings lists

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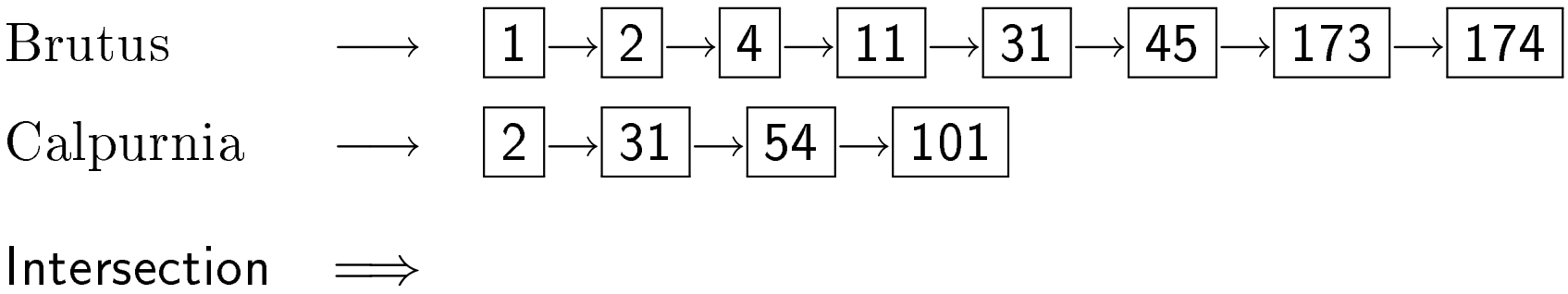
  4. Retrieve its postings list from the postings file
  5. Intersect the two postings lists
  6. Return intersection to user

Intersecting two postings lists



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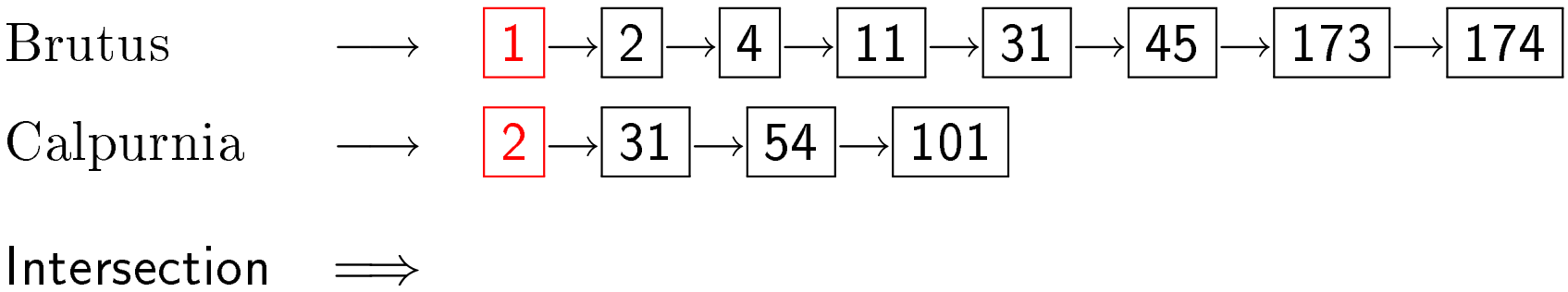

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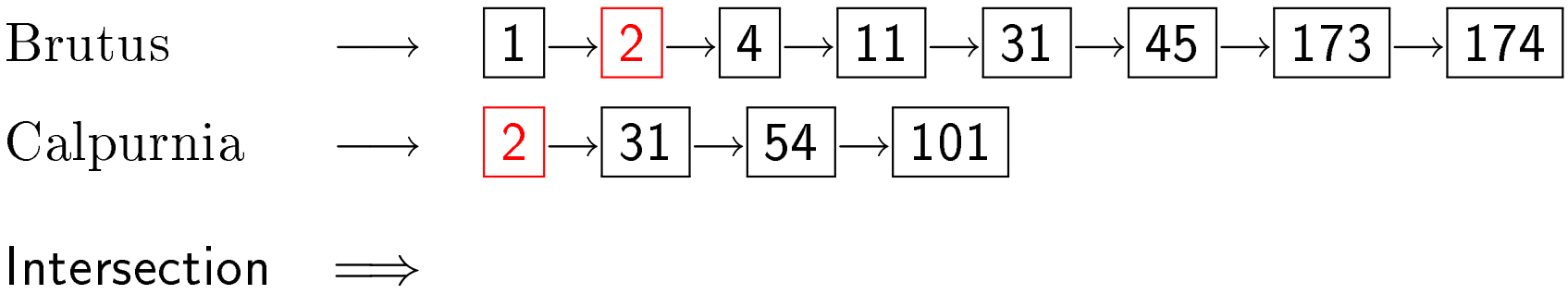

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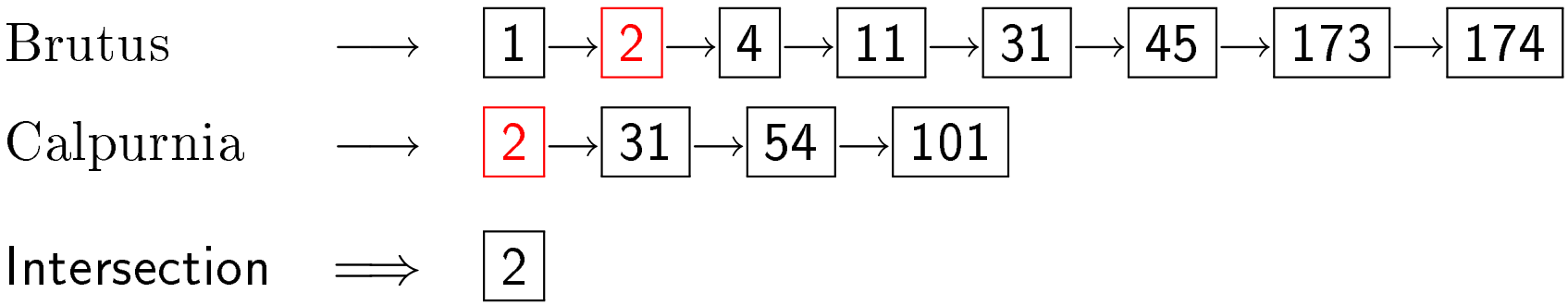

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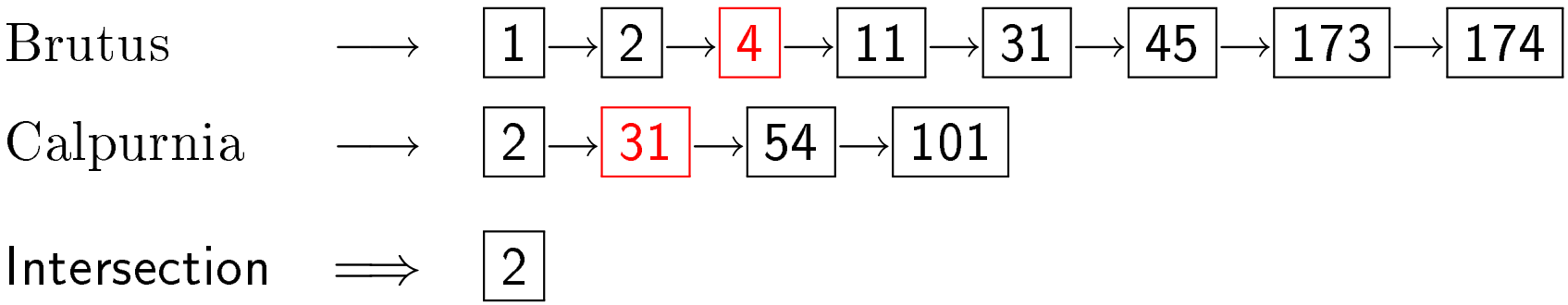

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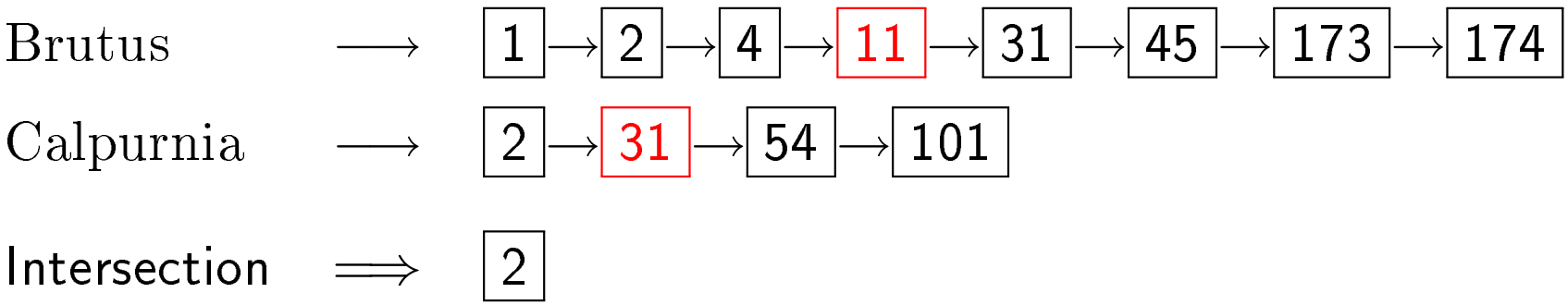

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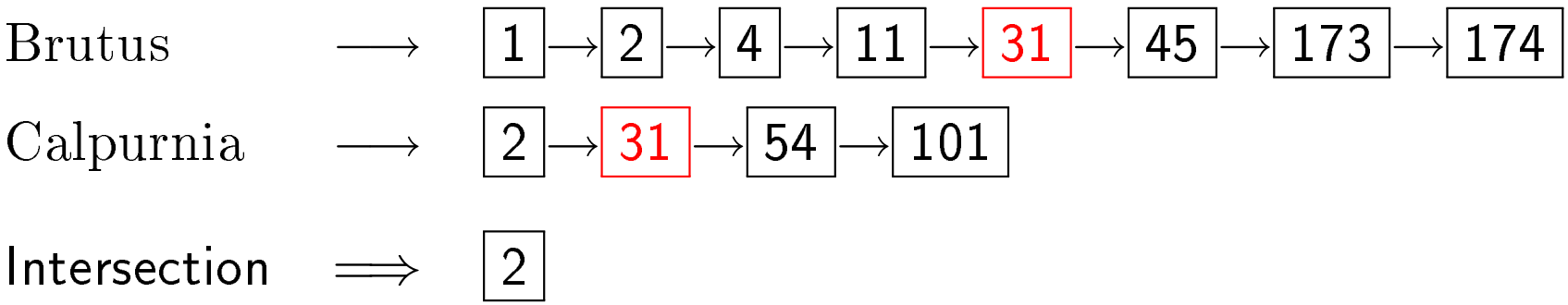

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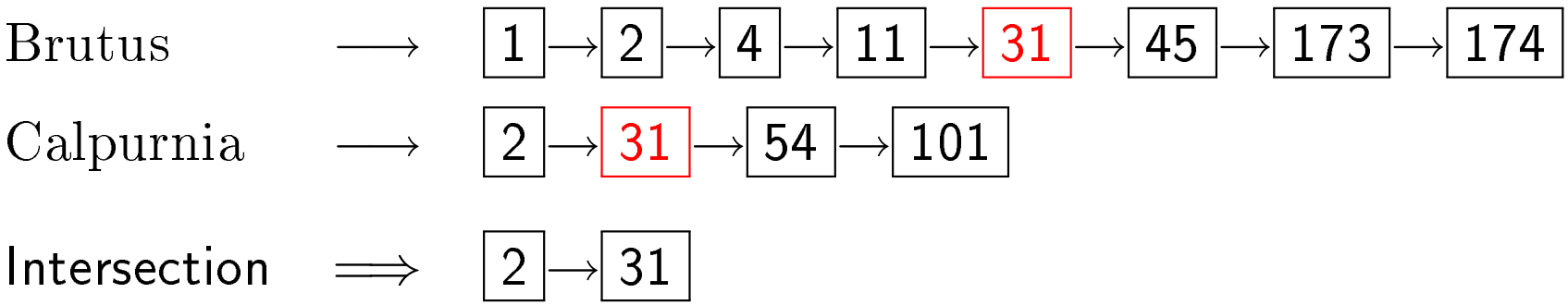

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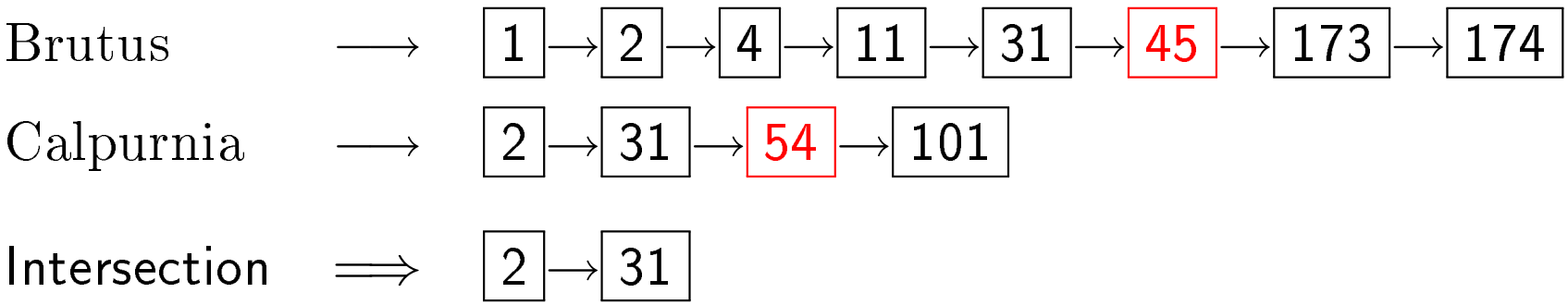

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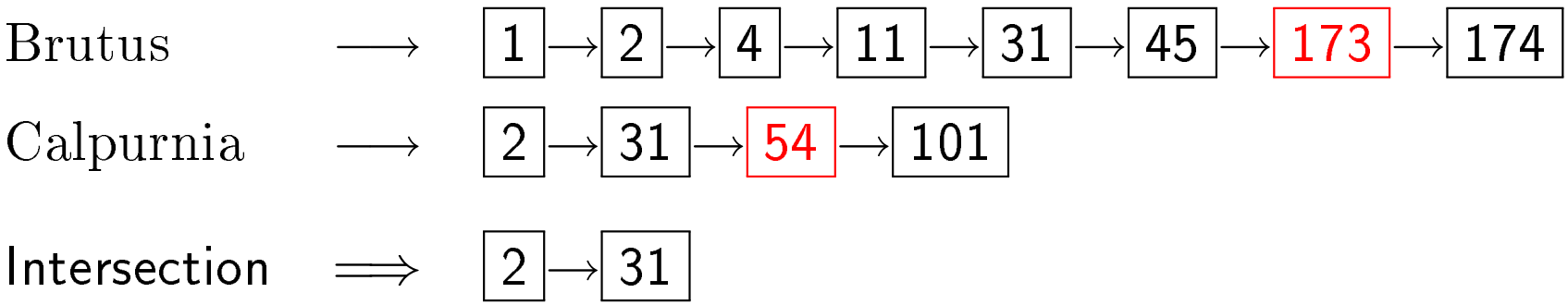

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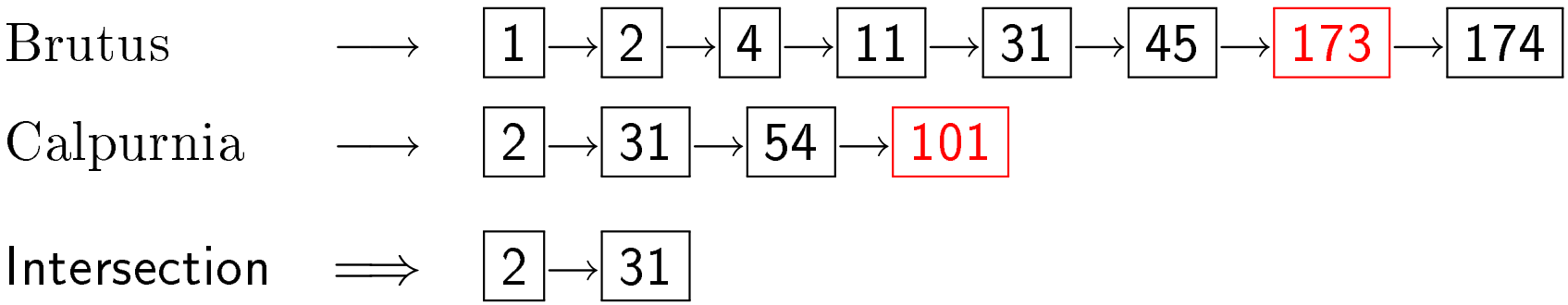

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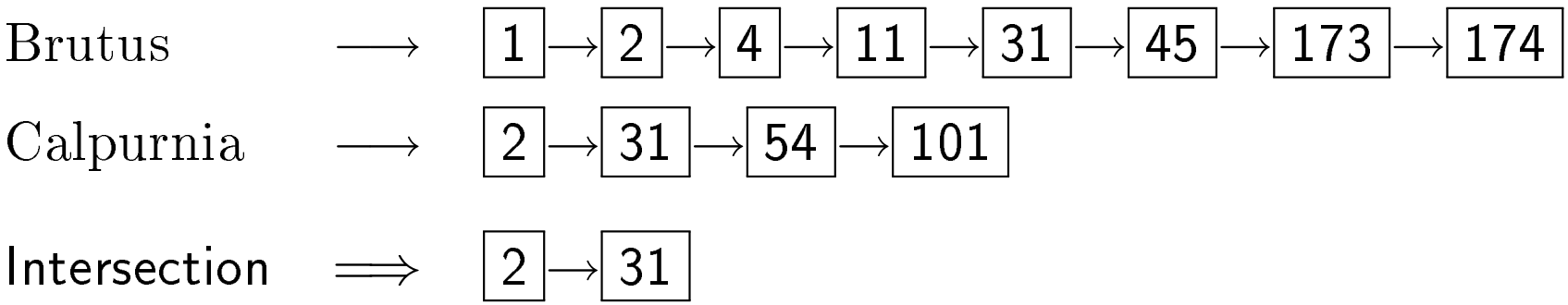

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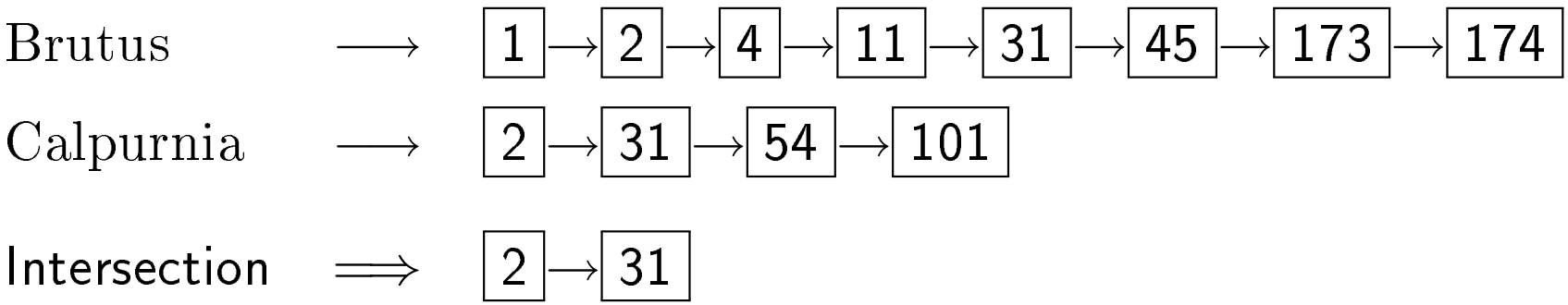

- This is linear in the length of the postings lists.
- This only works if postings lists are sorted.

Intersecting two postings lists

```
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

- The Boolean retrieval model can answer any query that is a Boolean expression.
  - Boolean queries are queries that use AND, OR and NOT to join query terms.
  - Views each document as a set of terms.
  - Is precise: Document matches condition or not.
- Primary commercial retrieval tool for 3 decades
- Many professional searchers (e.g., lawyers) still like Boolean queries
  - You know exactly what you are getting.
- Many search systems you use are also Boolean: email, intranet etc.

Query optimization

- What is the best order for query processing?
- Consider a query that is an AND of n terms, $n > 2$
- For each of the terms, get its postings list, then AND them together
- Example query: Brutus AND Calpurnia AND Caesar

Query optimization

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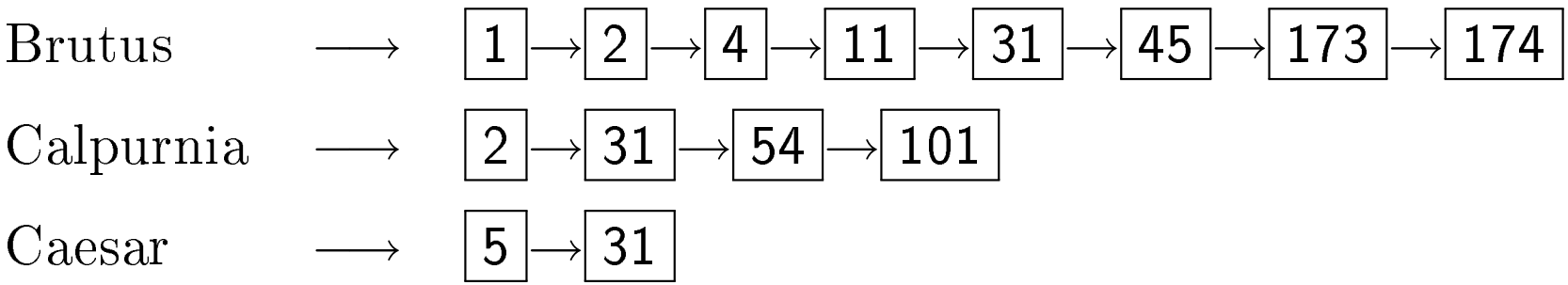
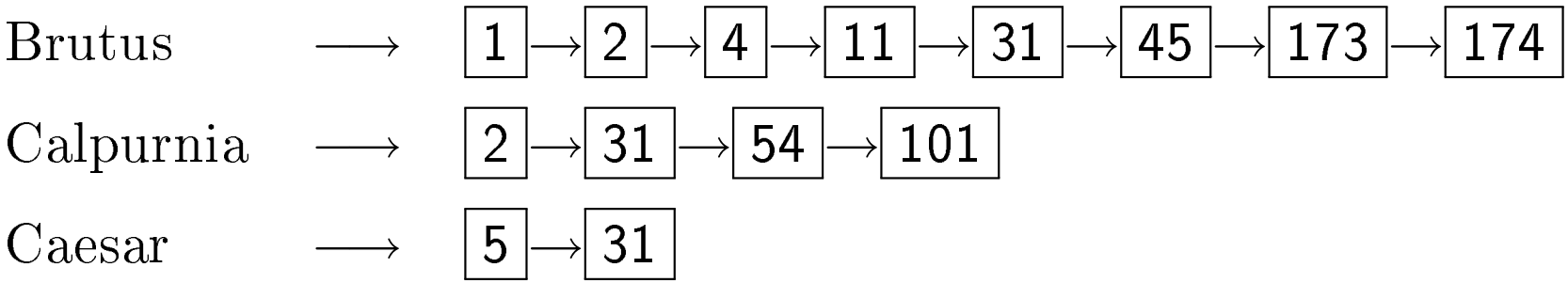


Query optimization

- Example query: Brutus AND Calpurnia AND Caesar
- Simple and effective optimization: Process in order of increasing frequency
- Start with the shortest postings list, then keep cutting further
- In this example, first Caesar, then Calpurnia, then Brutus



Optimized intersection algorithm for conjunctive queries

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```

More general optimization

- Example query: (madding OR crowd) AND (ignoble OR strife)
- Get frequencies for all terms
- Estimate the size of each OR by the sum of its frequencies (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)


H. S. Christopher Manning, P. Raghavan.
Introduction to Information Retrieval.
Cambridge, 2008.