Introduction to Information Retrieval

http://informationretrieval.org

IIR 2: The term vocabulary and postings lists

Hinrich Schütze

Institute for Natural Language Processing, Universität Stuttgart

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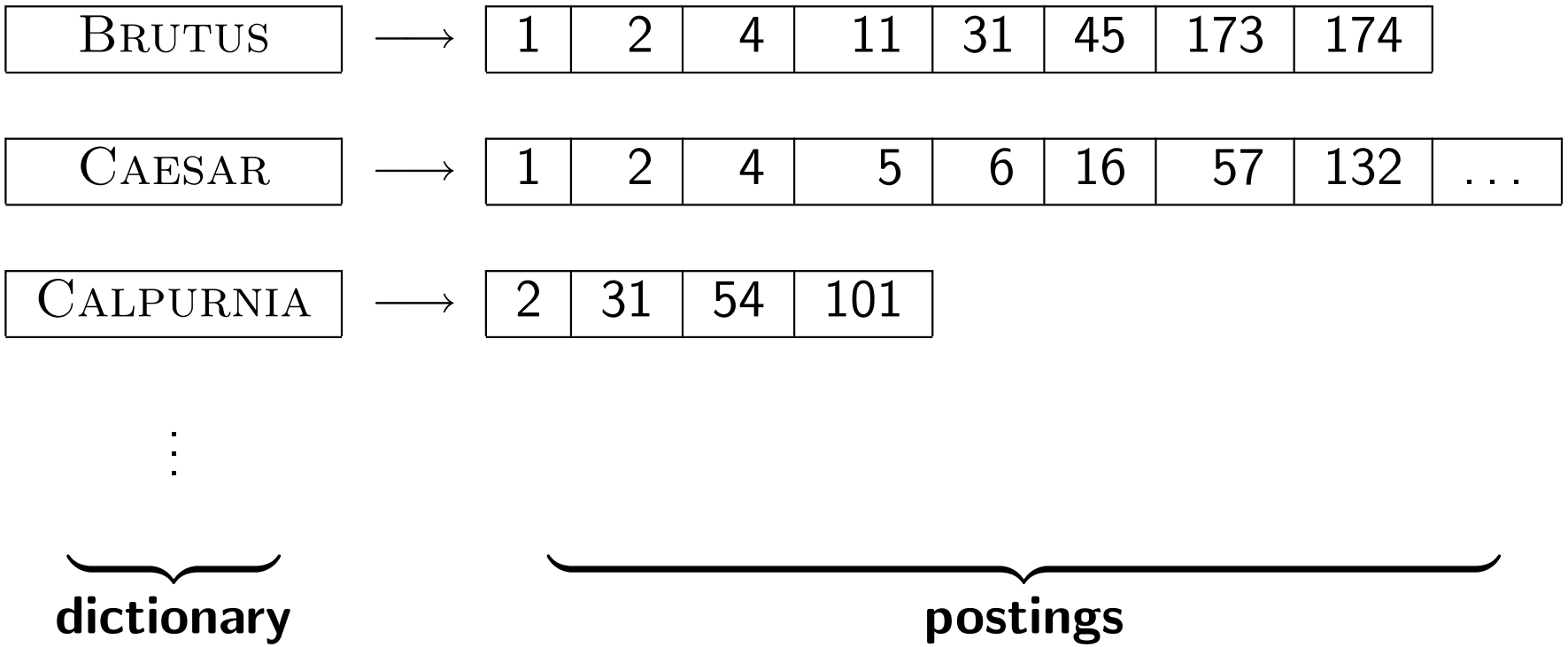
Overview

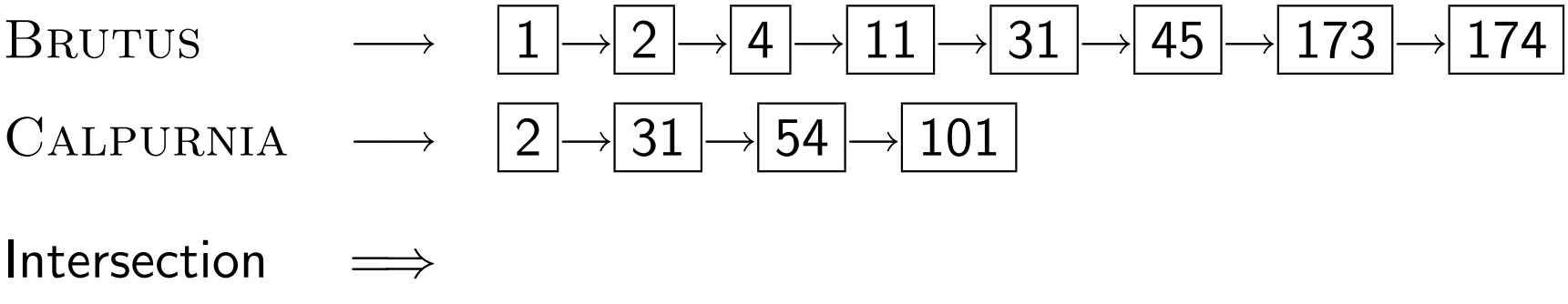
Outline

Inverted index

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



Intersecting two postings lists



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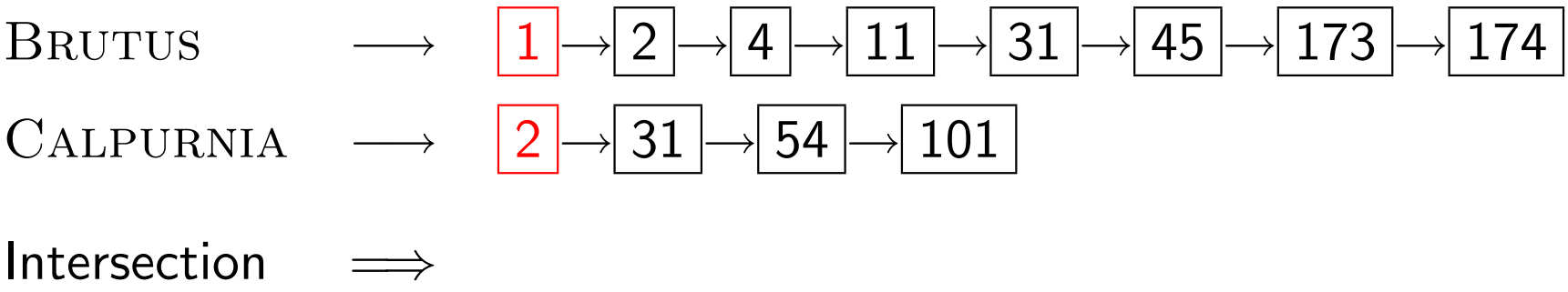

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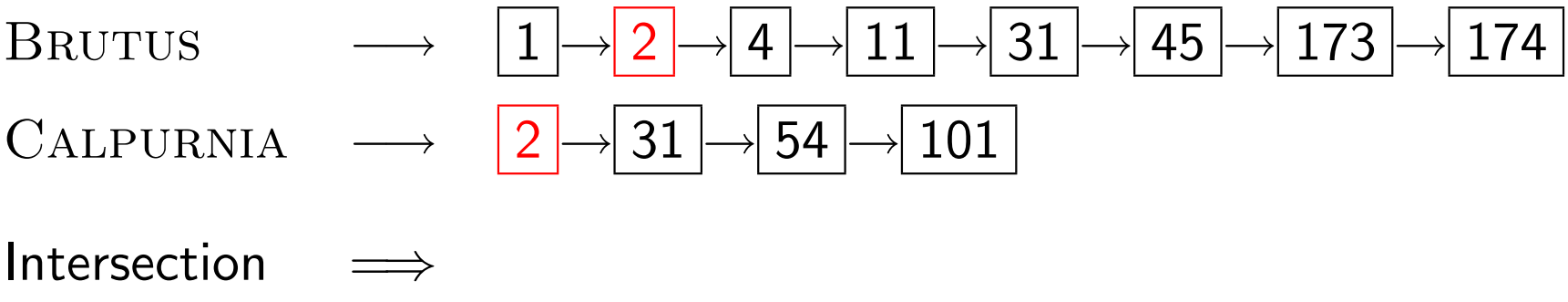

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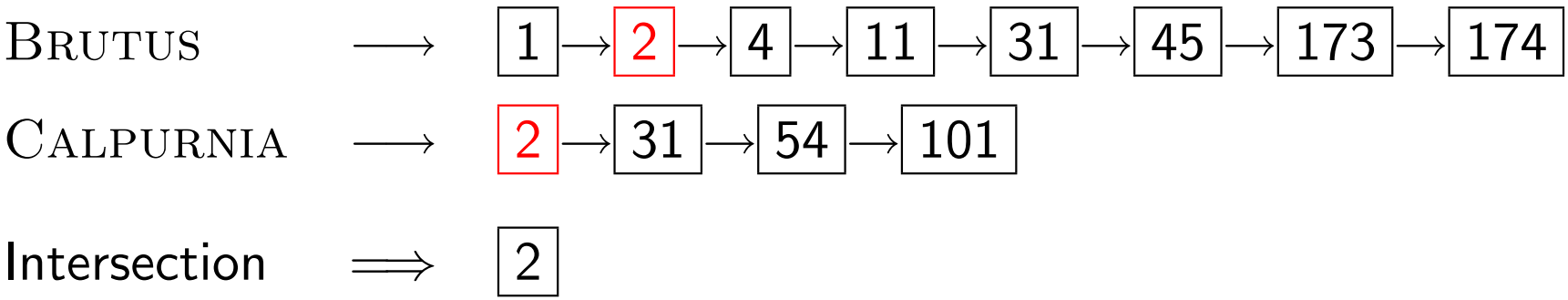

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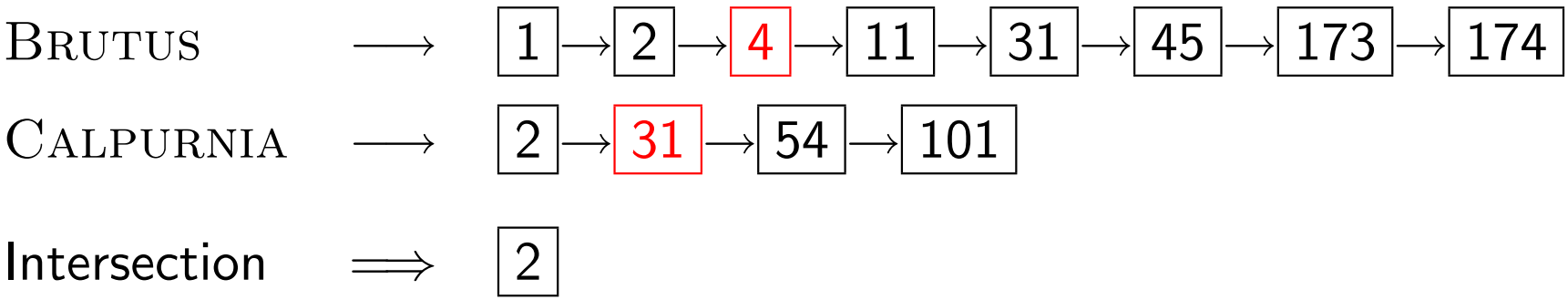

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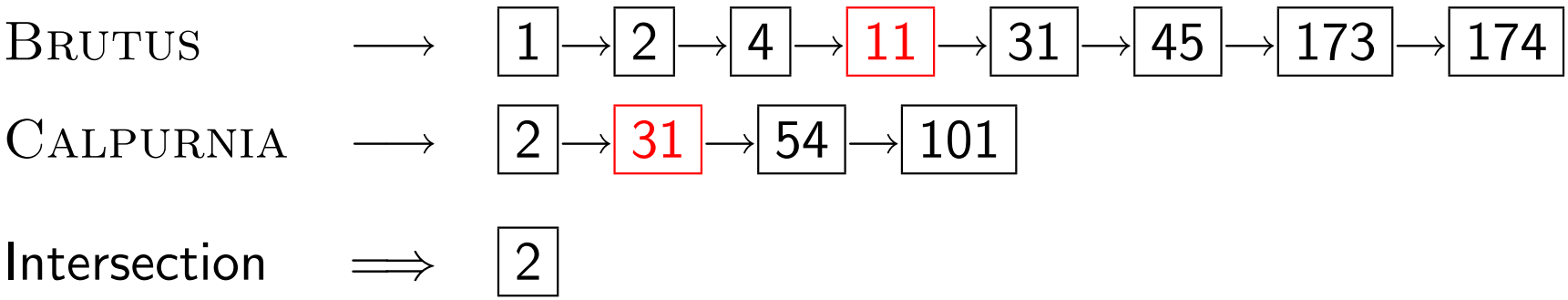

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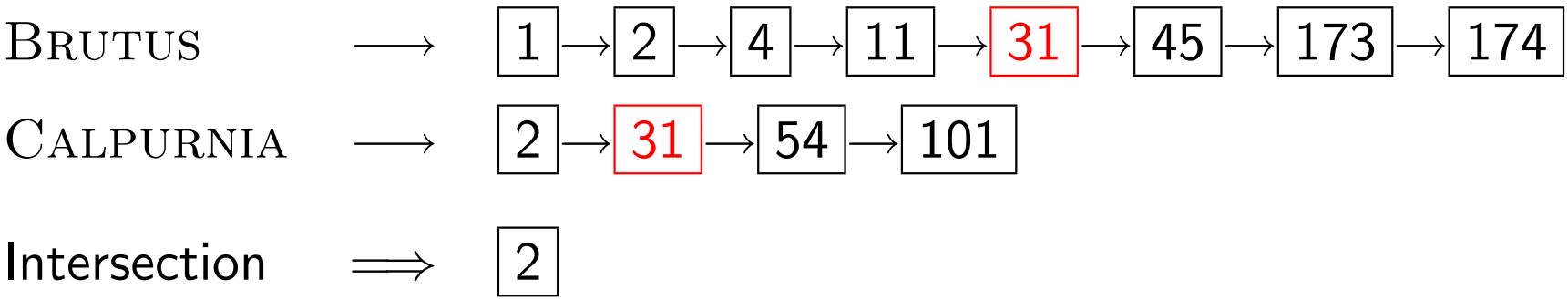

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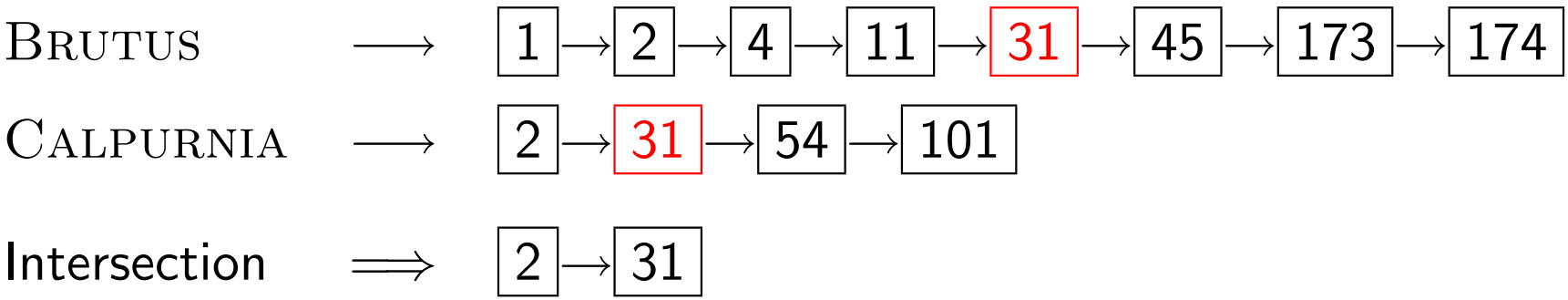

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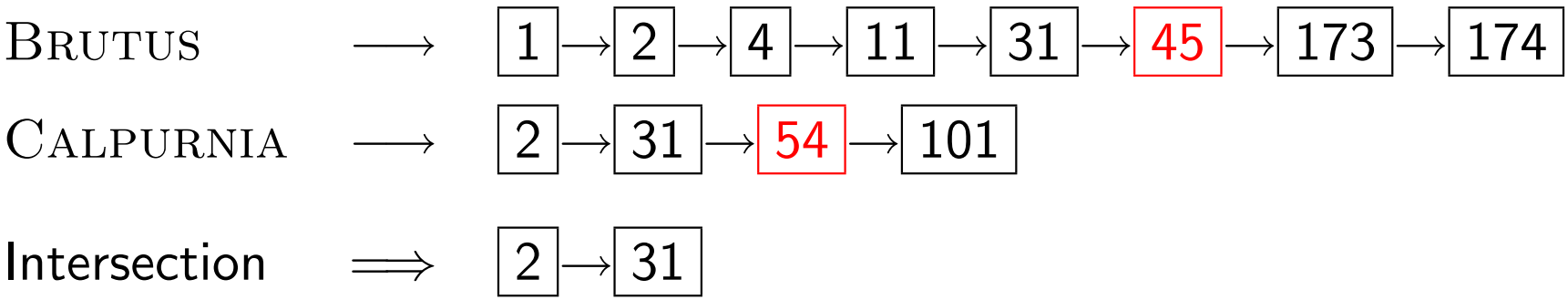

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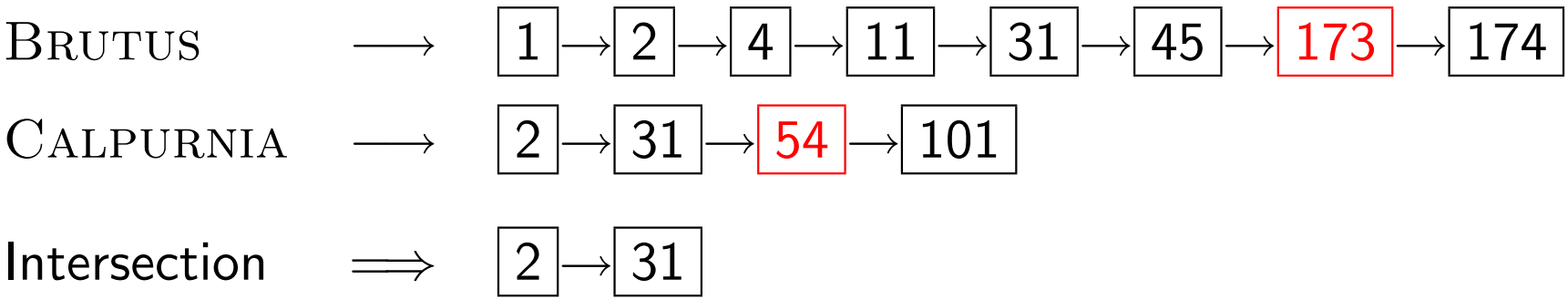

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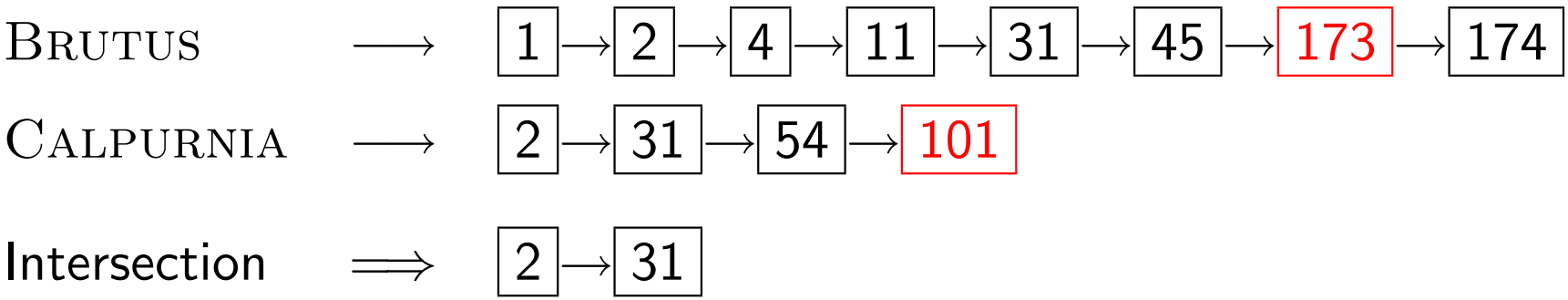

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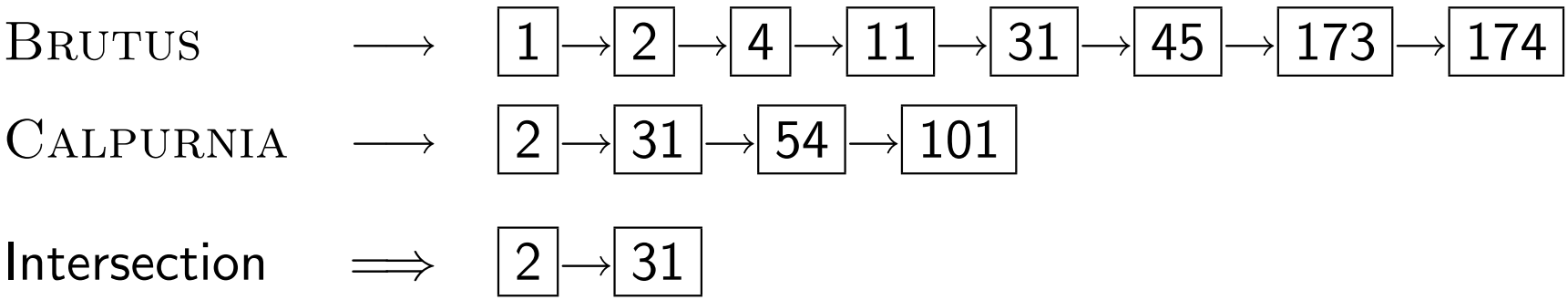

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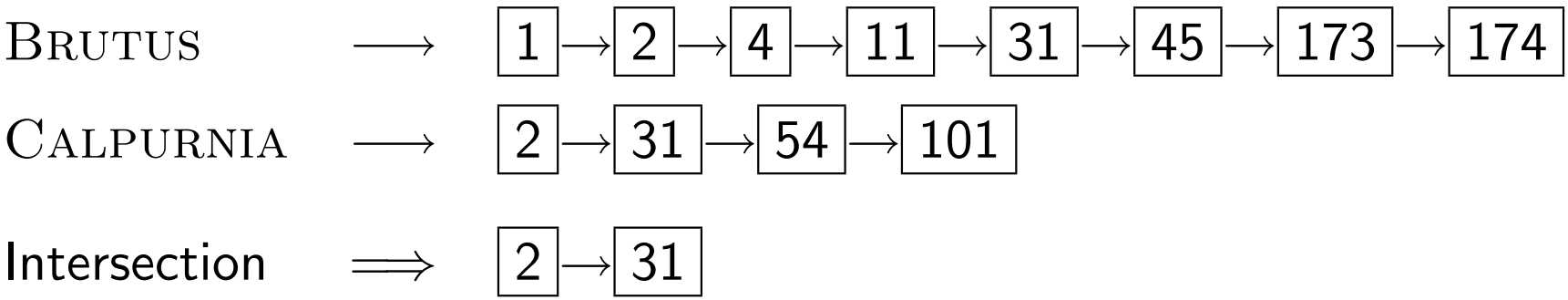

- Linear in the length of the postings lists.

Constructing the inverted index: Sort postings

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
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killed	1
let	2
me	1
noble	2
so	2
the	1
the	2
told	2
you	2
was	1
was	2
with	2

Westlaw: Example queries

Information need: Information on the legal theories involved in preventing the disclosure of trade secrets by employees formerly employed by a competing company

Query: "trade secret" /s disclos! /s prevent /s employe!

Information need: Requirements for disabled people to be able to access a workplace

Query: disab! /p access! /s work-site work-place (employment /3 place)

Information need: Cases about a host's responsibility for drunk guests

Query: host! /p (responsib! liab!) /p (intoxicat! drunk!) /p guest

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  - We know what a term is.
- Both issues can be complex in reality.
- We'll look a little bit at what a document is.
- But mostly at terms: How do we define and process the vocabulary of terms of a collection?

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- Alternative: use heuristics

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  - French email with Spanish pdf attachment
- What is the document unit for indexing?
- A file?
- An email?
- An email with 5 attachments?
- A group of files (ppt or latex in HTML)?

Terms

Definitions

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- Token – An instance of a word or term occurring in a document.
- Type – The same as a term in most cases: an equivalence class of tokens.

Type/token distinction: Example

- *In June, the dog likes to chase the cat in the barn.*

Type/token distinction: Example

- *In June, the dog likes to chase the cat in the barn.*
- How many tokens? How many types?

Recall: Inverted index construction

- Input:

Friends, Romans, countrymen.	So let it be with Caesar	. . .

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- Input:

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- Each token is a candidate for a postings entry.
- What are valid tokens to emit?

Why tokenization is difficult – even in English

Example: *Mr. O'Neill thinks that the boys' stories about Chile's capital aren't amusing.*

Tokenize this sentence

One word or two? (or several)

- Hewlett-Packard

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- State-of-the-art

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- Los Angeles-based company
- cheap San Francisco-Los Angeles fares
- York University vs. New York University

Numbers

- 3/12/91

Numbers

- 3/12/91
- 12/3/91

Numbers

- 3/12/91
- 12/3/91
- Mar 12, 1991

Numbers

- 3/12/91
- 12/3/91
- Mar 12, 1991
- B-52

Numbers

- 3/12/91
- 12/3/91
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- B-52
- 100.2.86.144

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- Older IR systems may not index numbers, but generally it's a useful feature.

Chinese: No whitespace

莎拉波娃现在居住在美国东南部的佛罗里达。今年４月９日，莎拉波娃在美国第一大城市纽约度过了１８岁生日。生日派对上，莎拉波娃露出了甜美的微笑。

Ambiguous segmentation in Chinese

The two characters can be treated as one word meaning ‘monk’ or as a sequence of two words meaning ‘and’ and ‘still’.

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- Swedish, Finnish, Greek, Urdu, many other languages

Japanese

ノーベル平和賞を受賞したワンガリ・マータイさんが名誉会長を務めるＭＯＴＴＡＩＮＡＩキャンペーンの一環として、毎日新聞社とマガジンハウスは「私の、もったいない」を募集します。皆様が日ごろ「もったいない」と感じて実践していることや、それにまつわるエピソードを８００字以内の文章にまとめ、簡単な写真、イラスト、図などを添えて１０月２０日までにお送りください。大賞受賞者には、５０万円相当の旅行券とエコ製品２点の副賞が贈られます。

4 different "alphabets": Chinese characters, hiragana syllabary for inflectional endings and function words, katakana syllabary for transcription of foreign words and other uses, and latin. No spaces (as in Chinese).
End user can express query entirely in hiragana!

Arabic script

كِتَابٌ ⇐ ك ِ ت ا ب ٌ

un b ā t i k

/kitābun/ *‘a book’*

Arabic script: Bidirectionality

استقلت الجزائر في سنة 1962 بعد 132 عاما من الاحتلال الفرنسي.

← → ← → ← START

'Algeria achieved its independence in 1962 after 132 years of French occupation.'

Bidirectionality is not a problem if text is coded in Unicode.

Back to English

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- Why don't you want to put *window*, *Window*, *windows*, and *Windows* in the same equivalence class?

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- *He got his PhD from MIT.* $\rightarrow$ MIT $\neq$ mit

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- It's often best to lowercase everything since users will use lowercase regardless of correct capitalization.

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- Examples: *a*, *an*, *and*, *are*, *as*, *at*, *be*, *by*, *for*, *from*, *has*, *he*, *in*, *is*, *it*, *its*, *of*, *on*, *that*, *the*, *to*, *was*, *were*, *will*, *with*

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- Examples: *a*, *an*, *and*, *are*, *as*, *at*, *be*, *by*, *for*, *from*, *has*, *he*, *in*, *is*, *it*, *its*, *of*, *on*, *that*, *the*, *to*, *was*, *were*, *will*, *with*
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- Thesauri: IIR 9 (semantic equivalence, car = automobile)

What does Google do?

- Stop words
- Normalization
- Tokenization
- Lowercasing
- Stemming
- Non-latin alphabets
- Umlauts
- Compounds
- Numbers

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- Inflectional morphology (*cutting* → *cut*) vs. derivational morphology (*destruction* → *destroy*)

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- Example for derivational: *automate*, *automatic*, *automation* all reduce to *automat*

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- Sample convention: Of the rules in a compound command, select the one that applies to the longest suffix.

Porter stemmer: A few rules

Rule			**Example**		
SSES	$\rightarrow$	SS	caresses	$\rightarrow$	caress
IES	$\rightarrow$	I	ponies	$\rightarrow$	poni
SS	$\rightarrow$	SS	caress	$\rightarrow$	caress
S	$\rightarrow$		cats	$\rightarrow$	cat

Three stemmers: A comparison

Sample text: Such an analysis can reveal features that are not easily visible from the variations in the individual genes and can lead to a picture of expression that is more biologically transparent and accessible to interpretation

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Lovins stemmer: such an analys can reve featur that ar not eas vis from th vari in th individu gen and can lead to a pictur of expres that is mor biolog transpar and acces to interpres

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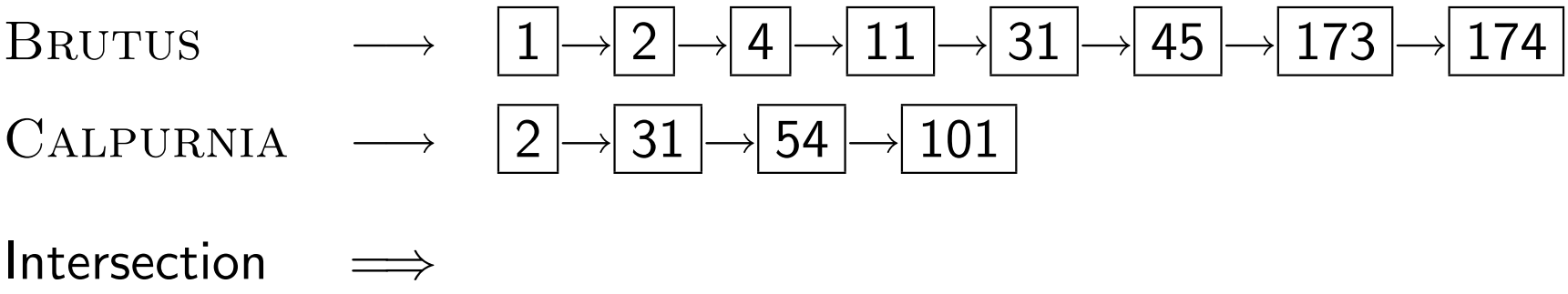
- Porter Stemmer equivalence class *oper* contains all of *operate operating operates operation operative operatives operational*.
- Queries where stemming hurts: "operational AND research", "operating AND system", "operative AND dentistry"

Interesting issues in your native language?

Outline

Recall basic intersection algorithm



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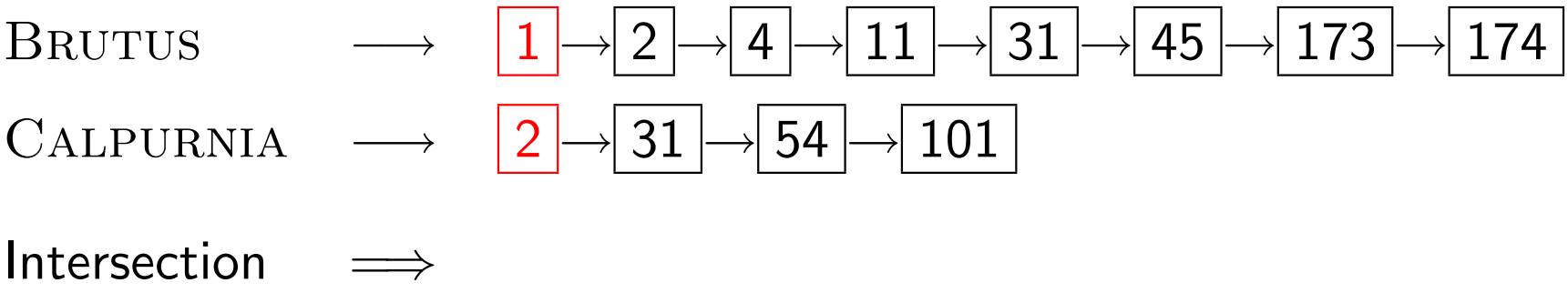

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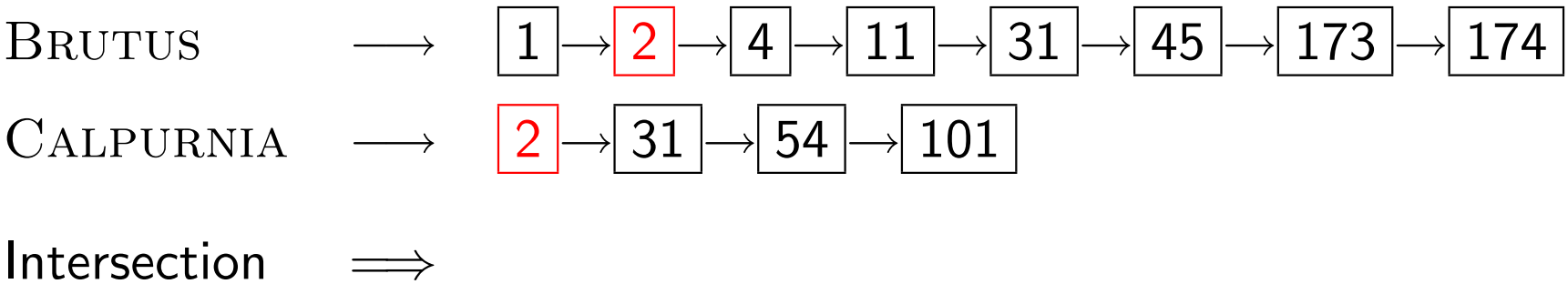

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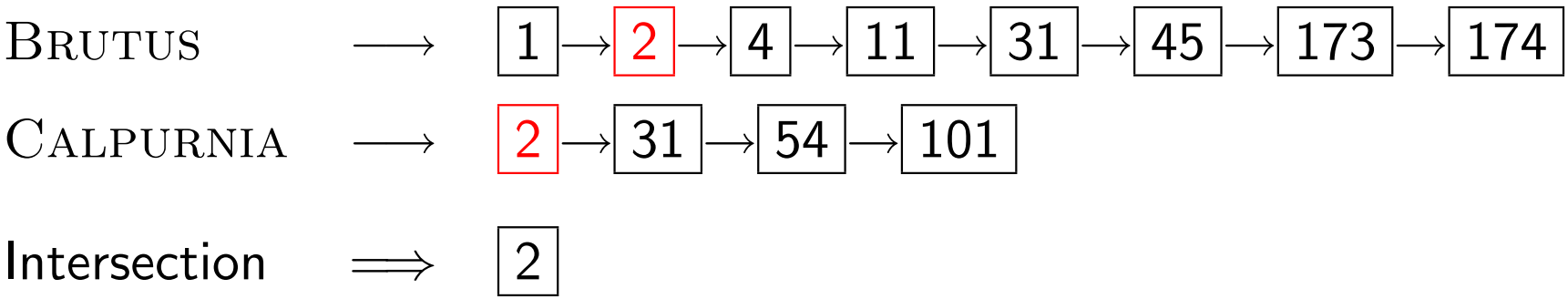

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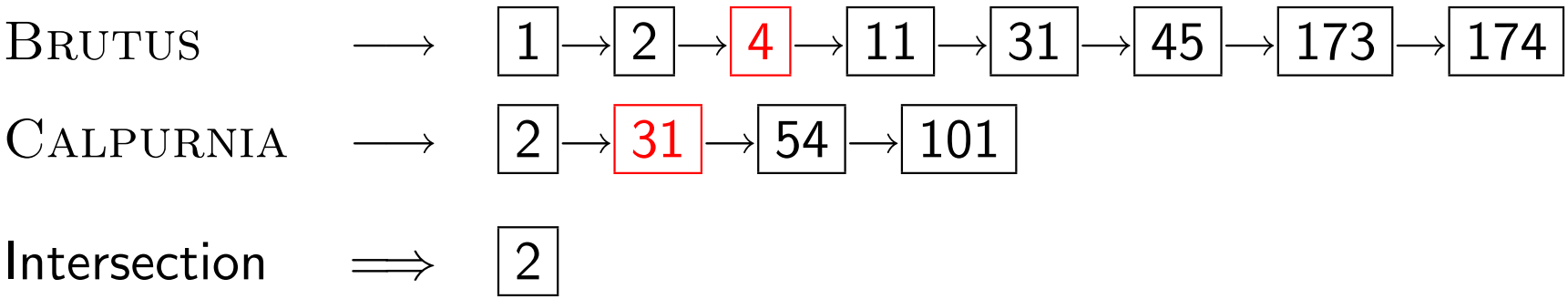

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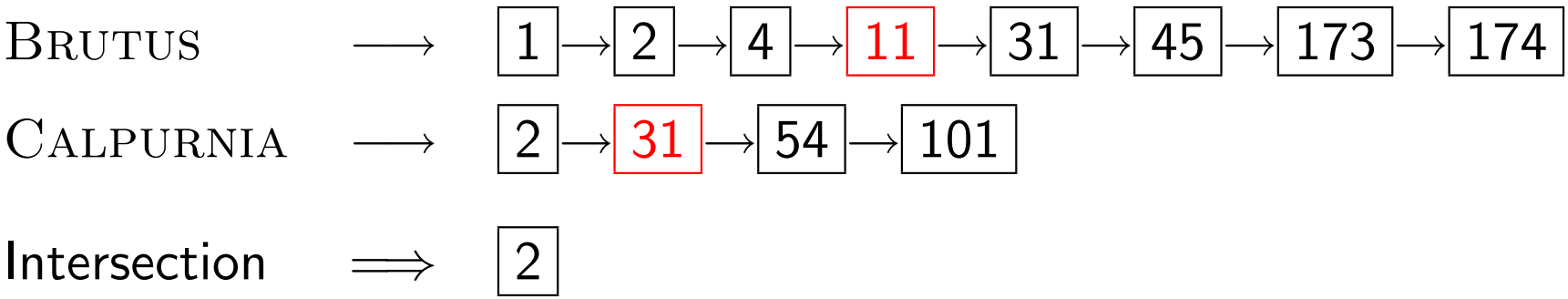

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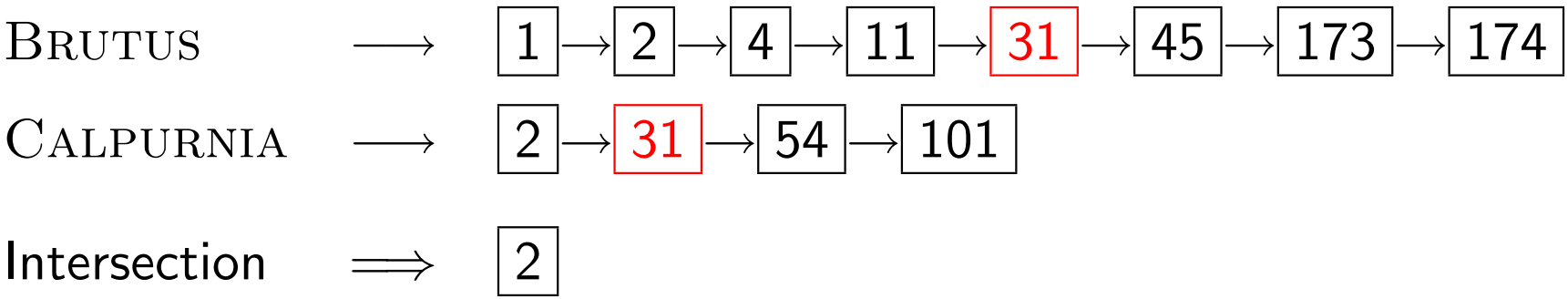

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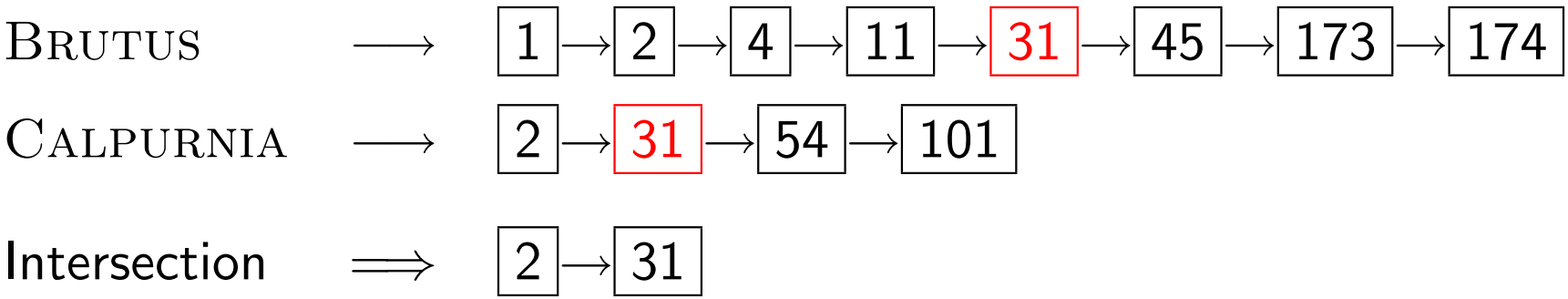

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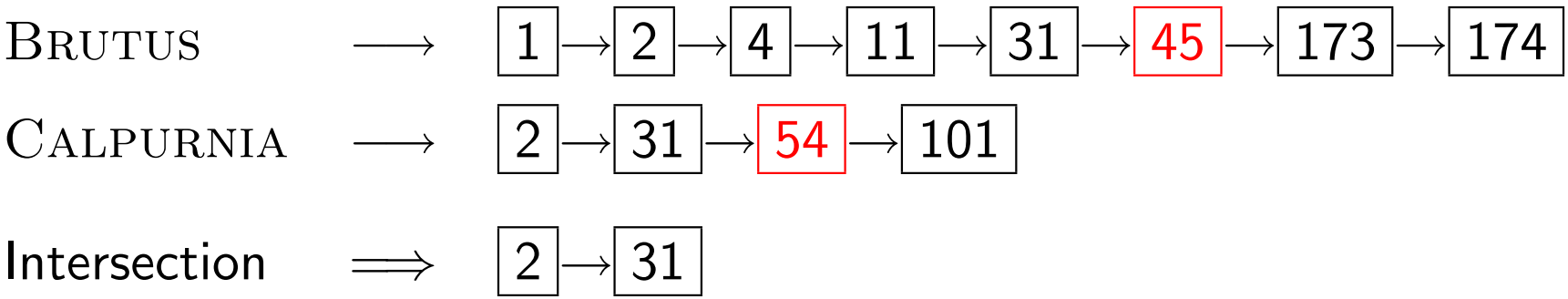

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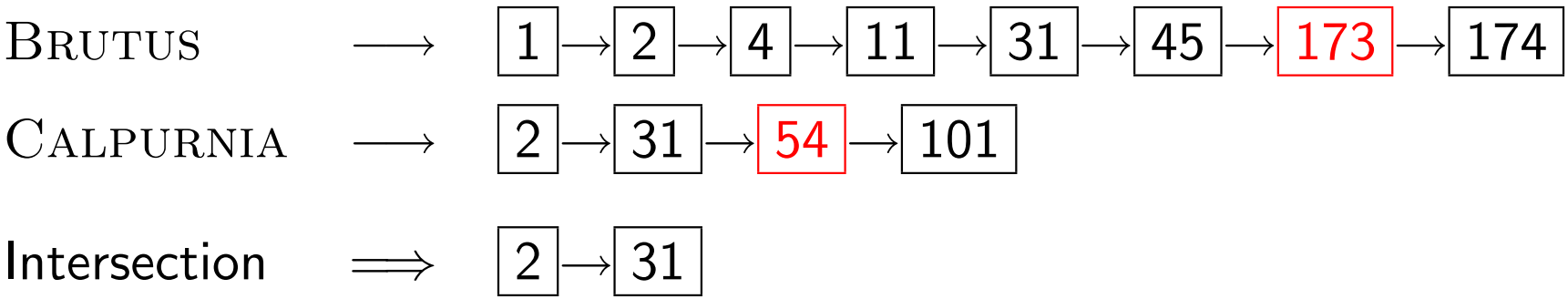

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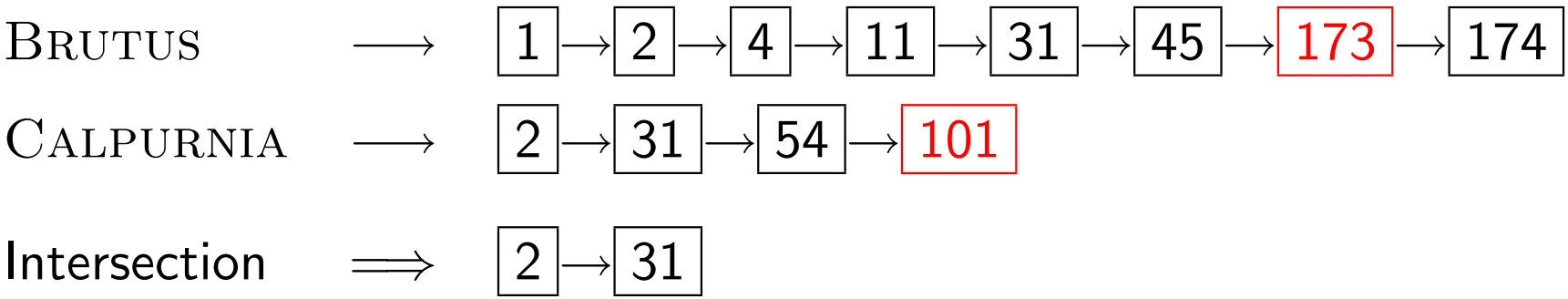

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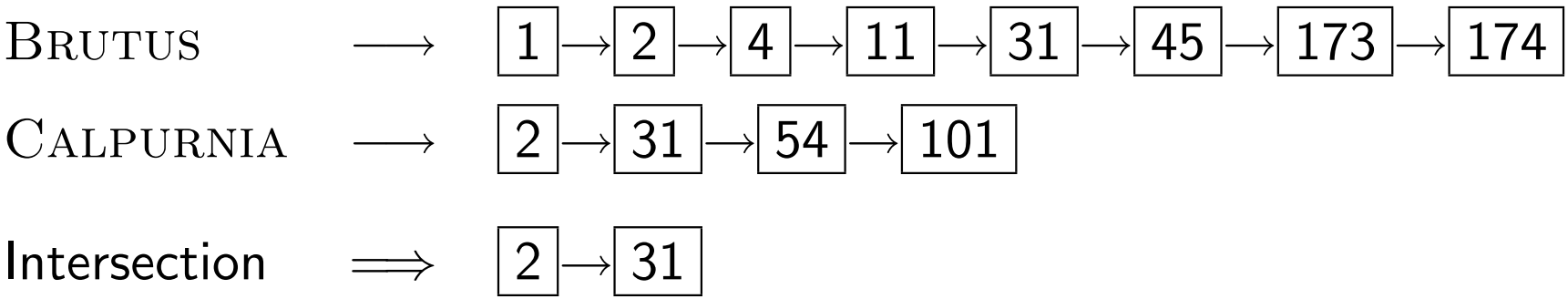

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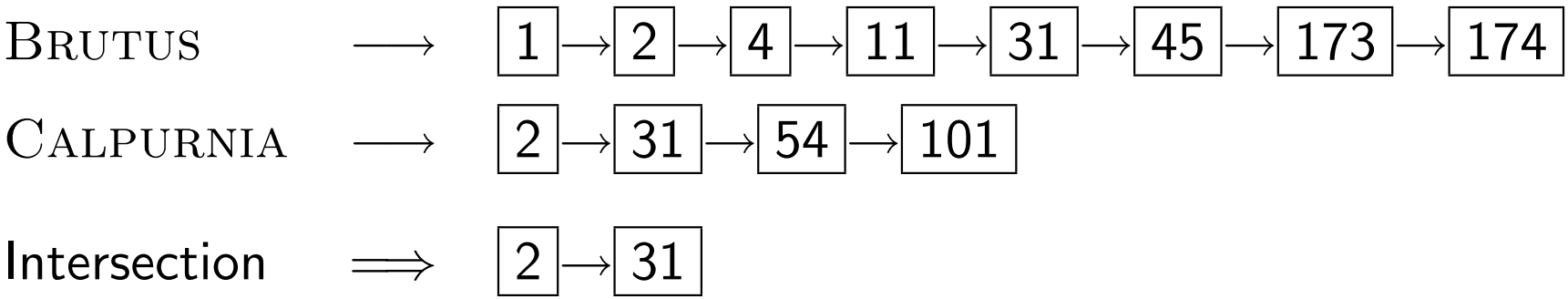

- Can we do better?

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- Where do we put skip pointers?
- How do we make sure results don't change?

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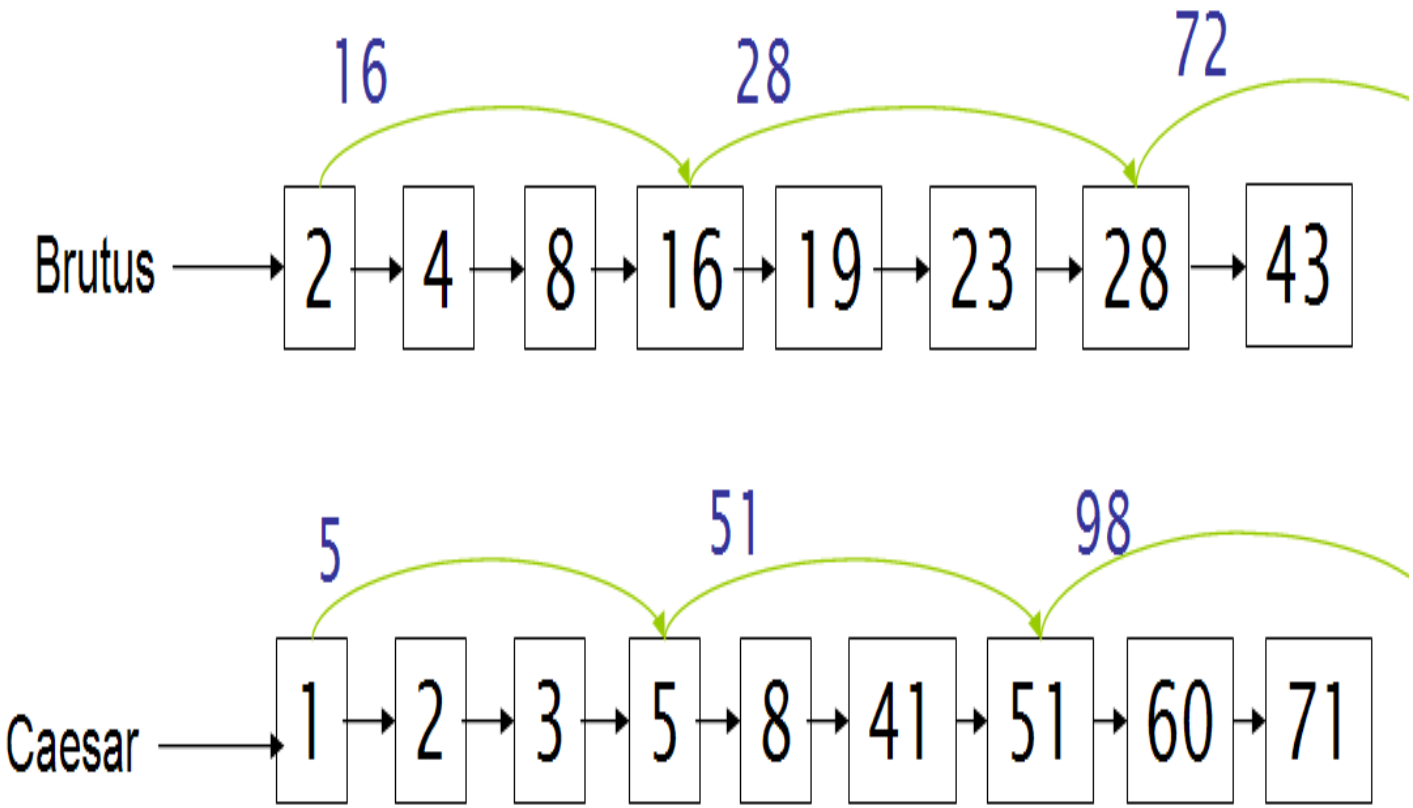
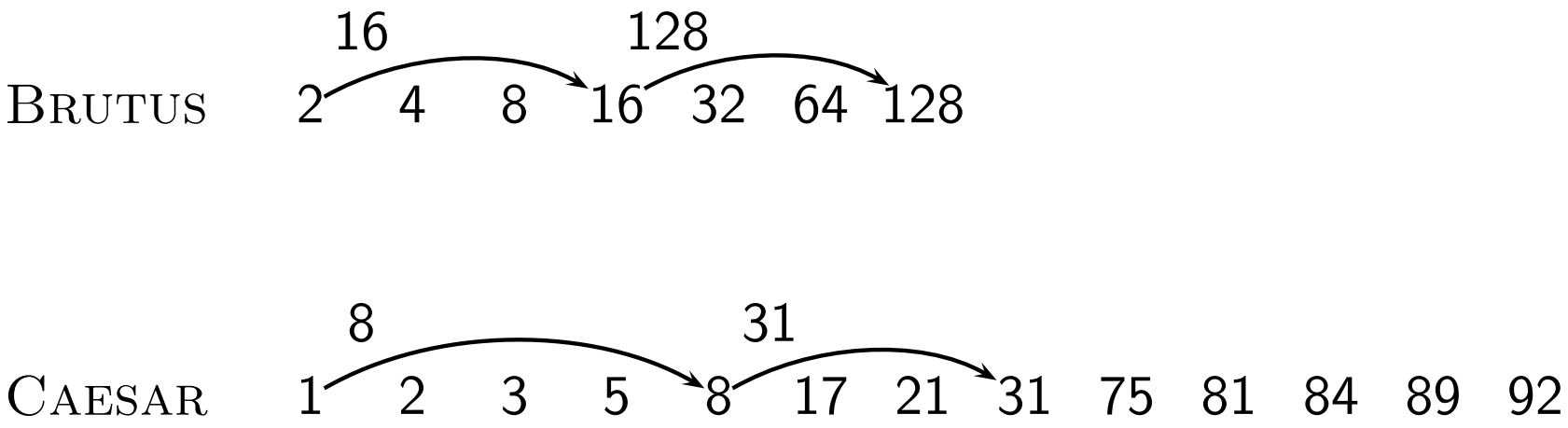


Basic idea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BRUTUS
2 4 8 16 32 64 128
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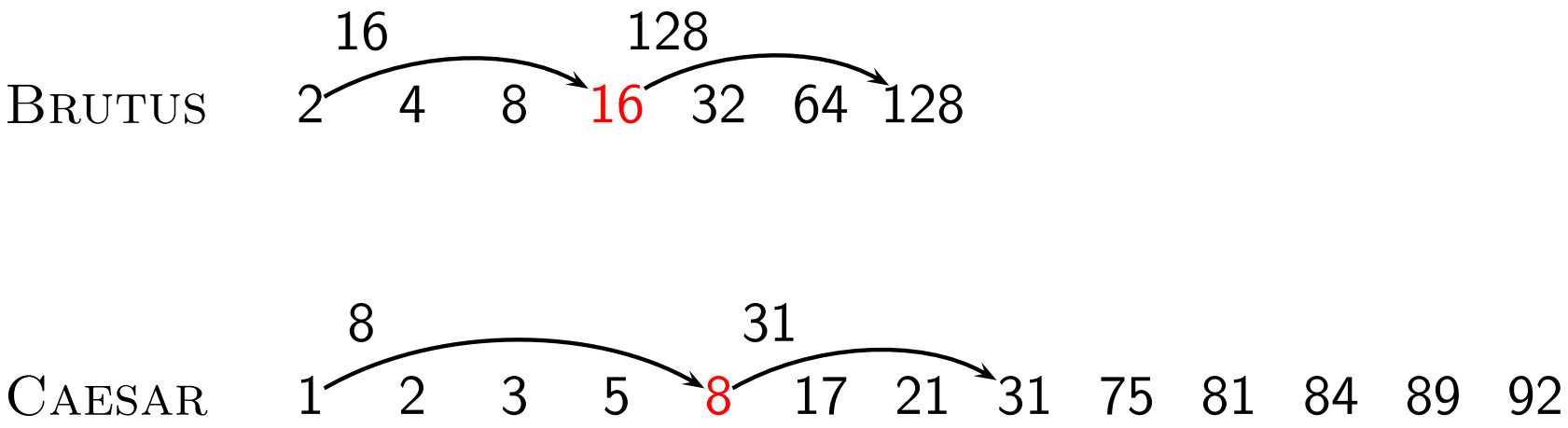
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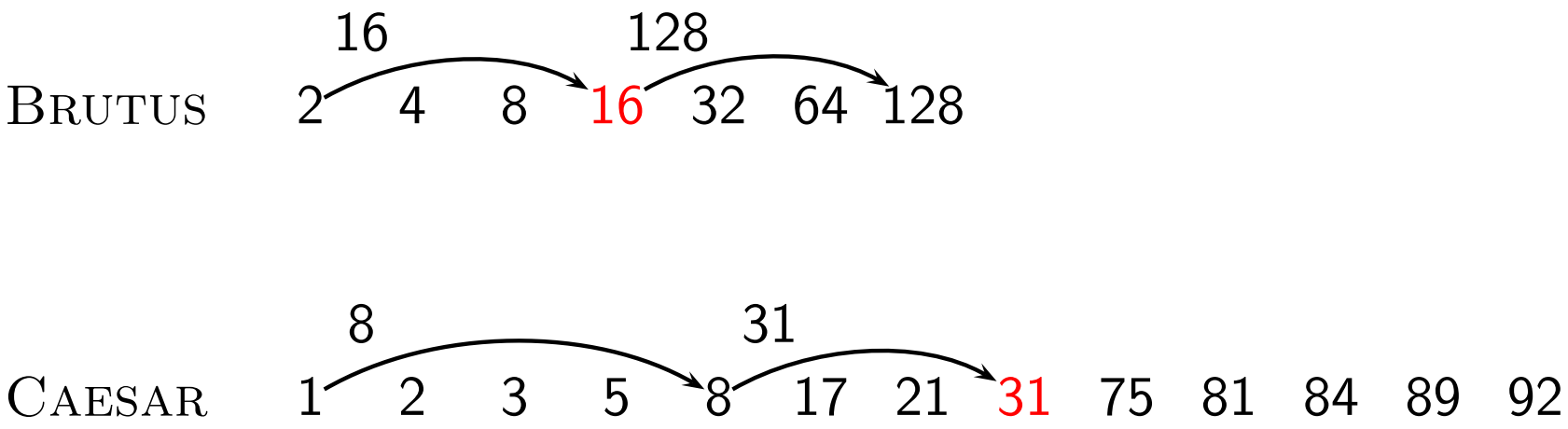
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Intersecting with skip pointers

```
IntersectWithSkips(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 if hasSkip(p1) and (docID(skip(p1)) ≤ docID(p2))
 9                     then p1 ← skip(p1)
10                     else p1 ← next(p1)
11                else if hasSkip(p2) and (docID(skip(p2)) ≤ docID(p1))
12                     then p2 ← skip(p2)
13                     else p2 ← next(p2)
14  return answer
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- Fewer skips: Each skip pointer skips many items, but we can not use it very often.

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- With today's fast CPUs, they don't help that much anymore.

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- Any ideas?

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- Two-word phrases can now easily be answered.

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- We need to do post-filtering of hits to identify subset that actually contains the 4-word phrase.

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- Postings lists in a positional index: each posting is a docID and a list of positions
- Example: to_1 be_2 or_3 not_4 to_5 be_6

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2, 5: ⟨1, 17, 74, 222, 255⟩;
4, 5: ⟨8, 16, 190, 429, 433⟩;
5, 2: ⟨363, 367⟩;
7, 3: ⟨13, 23, 191⟩; . . . ⟩

BE, 178239:
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Document 4 is a match!

Exercise

Shown below is a portion of a positional index in the format: term: doc1: ⟨position1, position2, . . . ⟩; doc2: ⟨position1, position2, . . . ⟩; etc.

ANGELS: *2: ⟨36,174,252,651⟩; 4: ⟨12,22,102,432⟩; 7: ⟨17⟩;*
FOOLS: *2: ⟨1,17,74,222⟩; 4: ⟨8,78,108,458⟩; 7: ⟨3,13,23,193⟩;*
FEAR: *2: ⟨87,704,722,901⟩; 4: ⟨13,43,113,433⟩; 7: ⟨18,328,528⟩;*
IN: *2: ⟨3,37,76,444,851⟩; 4: ⟨10,20,110,470,500⟩; 7: ⟨5,15,25,195⟩;*
RUSH: *2: ⟨2,66,194,321,702⟩; 4: ⟨9,69,149,429,569⟩; 7: ⟨4,14,404⟩;*
TO: *2: ⟨47,86,234,999⟩; 4: ⟨14,24,774,944⟩; 7: ⟨199,319,599,709⟩;*
TREAD: *2: ⟨57,94,333⟩; 4: ⟨15,35,155⟩; 7: ⟨20,320⟩;*
WHERE: *2: ⟨67,124,393,1001⟩; 4: ⟨11,41,101,421,431⟩; 7: ⟨16,36,736⟩;*

Which document(s) if any match each of the following two queries, where each expression within quotes is a phrase query?: "fools rush in", "fools rush in" AND "angels fear to tread"

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- For example: employment /3 place
- Find all documents that contain EMPLOYMENT and PLACE within 3 words of each other.
- *Employment agencies that place healthcare workers are seeing growth* is a hit.
- *Employment agencies that help place healthcare workers are seeing growth* is not a hit.

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- Simplest algorithm: look at cross-product of positions of (i) EMPLOYMENT in document and (ii) PLACE in document

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- Note that we want to return the actual matching positions, not just a list of documents.
- This is important for dynamic summaries etc.

"Proximity" intersection

```
POSITIONALINTERSECT(p1, p2, k)
 1  answer ← ⟨ ⟩
 2  while p1 ≠ NIL and p2 ≠ NIL
 3  do if docID(p1) = docID(p2)
 4        then l ← ⟨ ⟩
 5             pp1 ← positions(p1)
 6             pp2 ← positions(p2)
 7             while pp1 ≠ NIL
 8             do while pp2 ≠ NIL
 9                do if |pos(pp1) − pos(pp2)| ≤ k
10                      then ADD(l, pos(pp2))
11                      else if pos(pp2) > pos(pp1)
12                              then break
13                   pp2 ← next(pp2)
14                while l ≠ ⟨ ⟩ and |l[0] − pos(pp1)| > k
15                do DELETE(l[0])
16                for each ps ∈ l
17                do ADD(answer, ⟨docID(p1), pos(pp1), ps⟩)
18                pp1 ← next(pp1)
19             p1 ← next(p1)
20             p2 ← next(p2)
21        else if docID(p1) < docID(p2)
22                then p1 ← next(p1)
23                else p2 ← next(p2)
24  return answer
```

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- For these biwords, increased speed compared to positional postings intersection is substantial.
- Combination scheme: Include frequent biwords as vocabulary terms in the index. Do all other phrases by positional intersection.
- Williams et al. (2004) evaluate a more sophisticated mixed indexing scheme. Faster than a positional index, at a cost of 26% more space for index.

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- Let's look at the example of phrase queries.
- Why are they more expensive than regular Boolean queries?
- Can you demonstrate on Google that phrase queries are more expensive than Boolean queries?

Resources

- Chapter 2 of IIR

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- Resources at `http://ifnlp.org/ir`

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