

Introduction to Information Retrieval

<http://informationretrieval.org>

IIR 2: The term vocabulary and postings lists

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Overview

- 1 Recap
- 2 Documents
- 3 Terms
 - General + Non-English
 - English
- 4 Skip pointers
- 5 Phrase queries

Outline

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Inverted index

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

BRUTUS	→	1	2	4	11	31	45	173	174
--------	---	---	---	---	----	----	----	-----	-----

CAESAR	→	1	2	4	5	6	16	57	132	...
--------	---	---	---	---	---	---	----	----	-----	-----

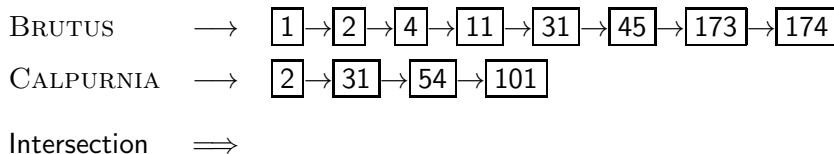
CALPURNIA	→	2	31	54	101
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⋮

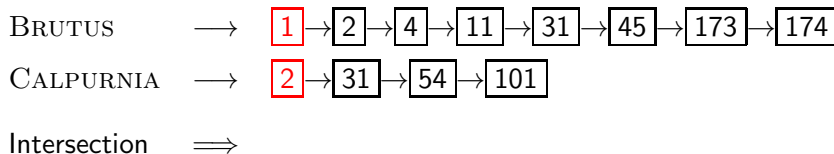

dictionary


postings

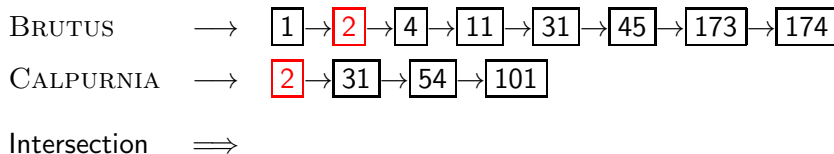
Intersecting two postings lists



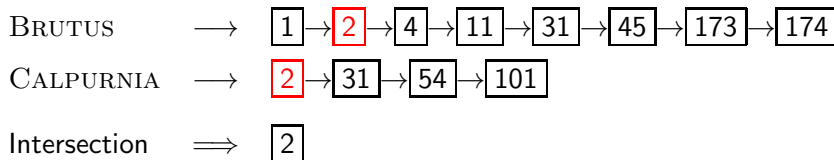
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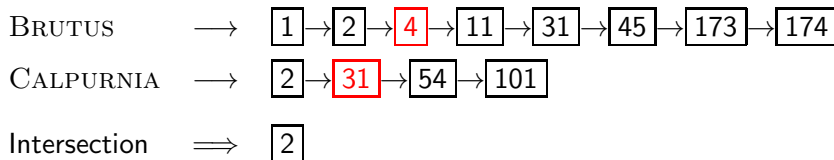
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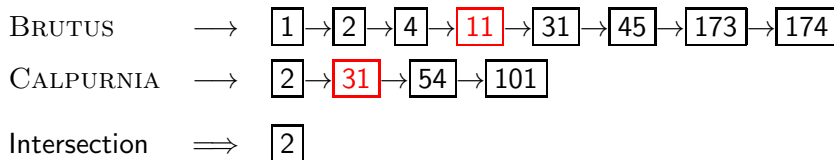
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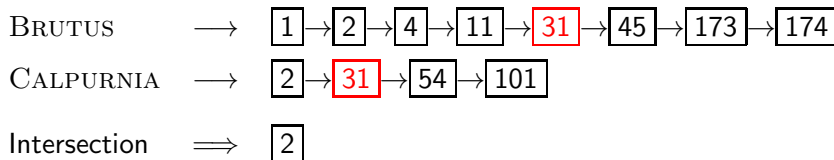
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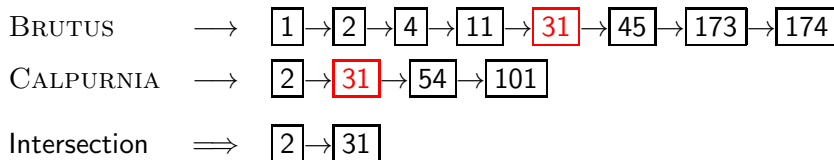
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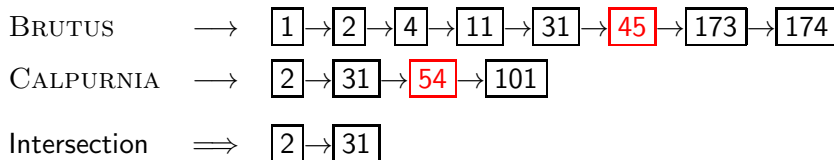
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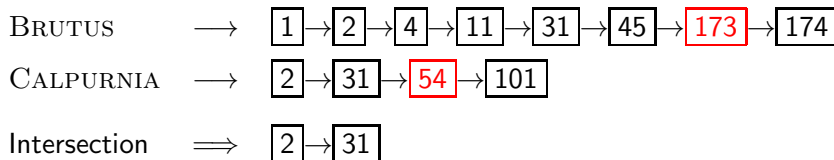
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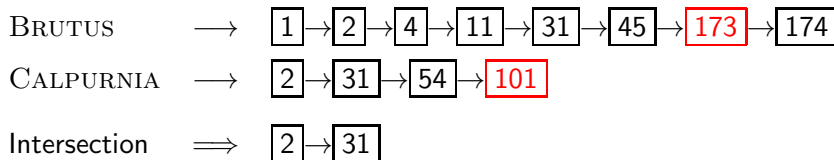
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Constructing the inverted index: Sort postings

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

Does Google use the Boolean model?

- On Google, the default interpretation of a query $[w_1 w_2 \dots w_n]$ is w_1 AND w_2 AND \dots AND w_n
- Cases where you get hits that do not contain one of the w_i :
 - anchor text
 - page contains variant of w_i (morphology, spelling correction, synonym)
 - long queries (n large)
 - boolean expression generates very few hits
- Simple Boolean vs. Ranking of result set
 - Simple Boolean retrieval returns matching documents in no particular order.
 - Google (and most well designed Boolean engines) rank the result set – they rank good hits (according to some estimator of relevance) higher than bad hits.

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- More complex indexes: skip pointers and phrases

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- This can be complex in reality.

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- Alternative: use heuristics

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- Also: XML

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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.* → MIT \neq mit

This means: every change if the original text loses information

Tokenization: Recall construction of inverted index

- Input:

Friends, Romans, countrymen.

So let it be with Caesar ...

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friend roman countryman so ... *normalized tokens*

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

Exercises

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

Why tokenization is difficult – even in English. **Tokenize:** *Mr. O'Neill thinks that the boys' stories about Chile's capital aren't amusing.*

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- Hewlett-Packard
- State-of-the-art
- co-education
- the hold-him-back-and-drag-him-away maneuver
- data base
- San Francisco
- Los Angeles-based company
- cheap San Francisco-Los Angeles fares
- York University vs. New York University

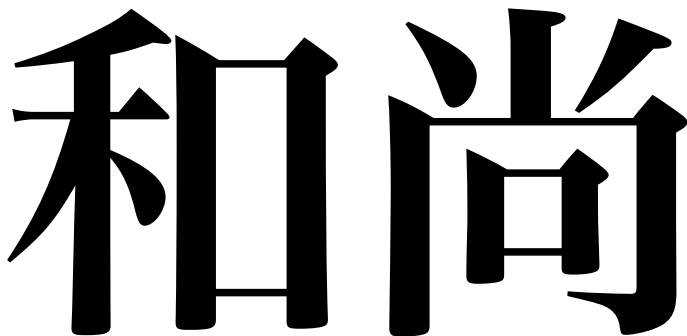
Numbers

- 3/20/91
- 20/3/91
- Mar 20, 1991
- B-52
- 100.2.86.144
- (800) 234-2333
- 800.234.2333
- 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 image shows two large, bold Chinese characters, '和' (he) and '尚' (shang), written in a traditional serif font. The character '和' is on the left and '尚' is on the right. They are positioned close together, illustrating the ambiguity of their segmentation.

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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- Inuit: tusaatsiarunnanngittualuujunga (I can't hear very well.)
- Many other languages with segmentation difficulties: Finnish, Urdu, ...

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MOTTA I N A I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。

Accents and diacritics

- Accents: résumé vs. resume (simple omission of accent)
- Umlauts: Universität vs. Universitaet (substitution with special letter sequence “ae”)
- Most important criterion: How are users likely to write their queries for these words?
- Even in languages that standardly have accents, users often do not type them. (Polish?)

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

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- Most web search engines index stop words.

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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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- Each phase consists of a set of commands.
 - Sample command: Delete final *ement* if what remains is longer than 1 character
 - replacement → replac
 - cement → cement
- Sample convention: Of the rules in a compound command, select the one that applies to the longest suffix.

Porter stemmer: A few rules

Rule

SSSES → SS

IES → I

SS → SS

S →

Example

caresses → caress

ponies → poni

caress → caress

cats → 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

Porter stemmer: such an analysi can reveal featur that ar not easili visibl from the variat in the individu gene and can lead to a pictur of express that is more biolog transpar and access to interpret

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 interpre

Paice stemmer: such an analys can rev feat that are not easy vis from the vary in the individ gen and can lead to a pict of express that is mor biolog transp and access to interpret

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- Queries where stemming hurts: [operational AND research], [operating AND system], [operative AND dentistry]

Exercise: What ~~does Google~~ do?

should you do?

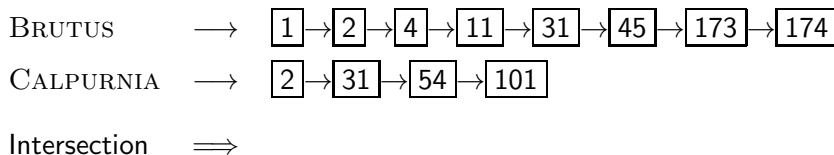
- Stop words
- Normalization
- Tokenization
- Lowercasing
- Stemming
- Non-latin alphabets
- Umlauts
- Compounds
- Numbers

Spoiler: there is no answer, it depends on your users' needs, your resources, the texts, ...

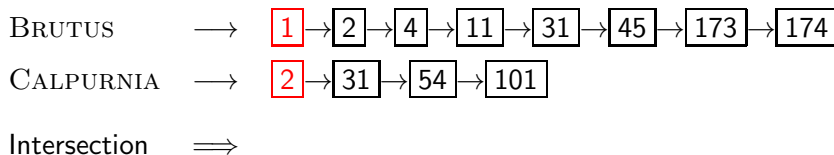
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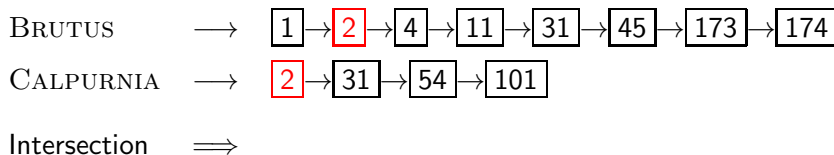
Recall basic intersection algorithm



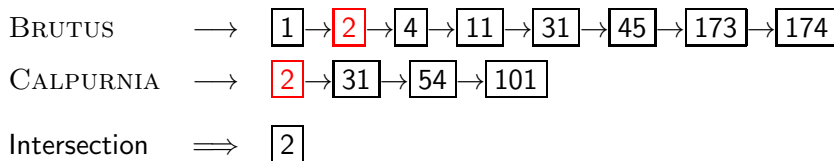
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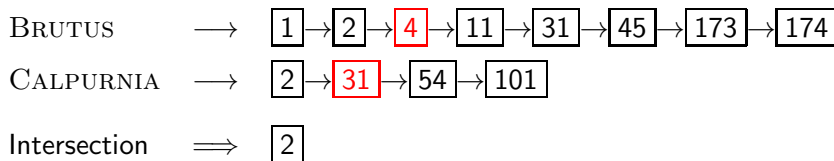
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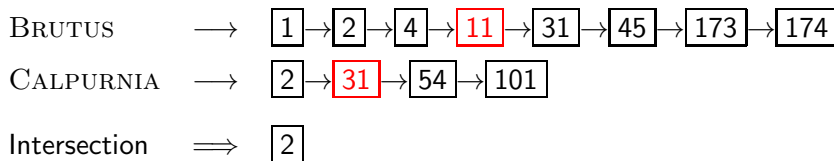
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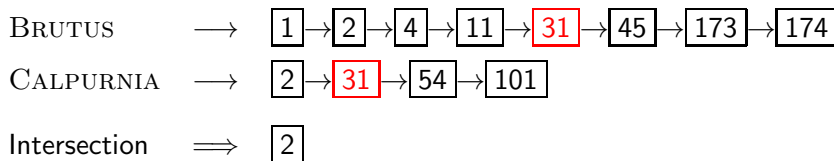
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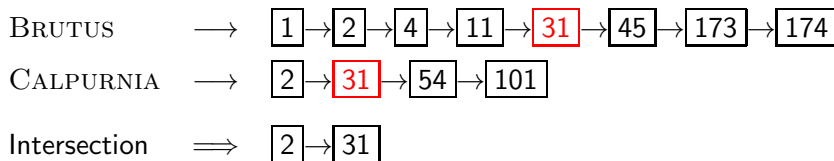
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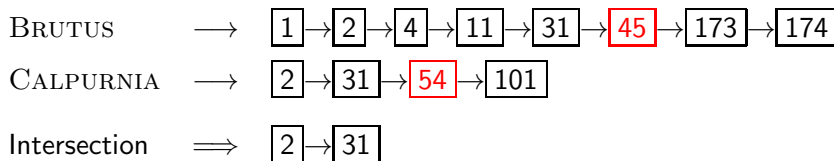
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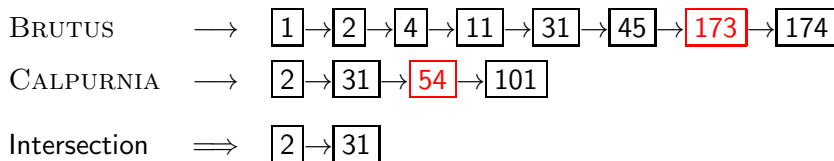
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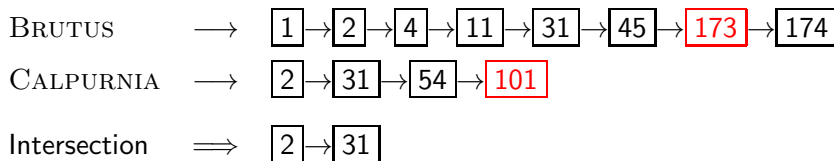
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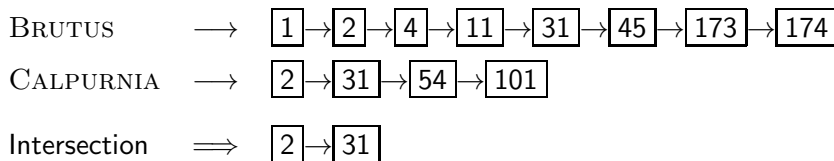
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- Linear in the length of the postings lists.
- Can we do better?

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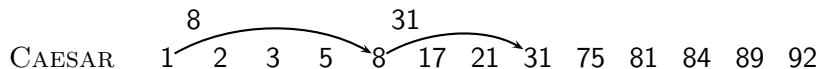
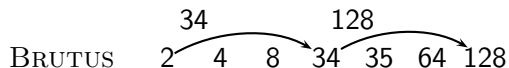
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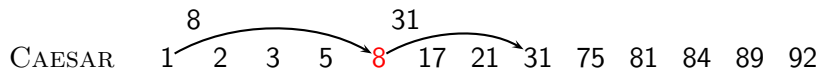
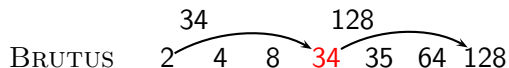
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- Where do we put skip pointers?
- How do we make sure intersection results are correct?

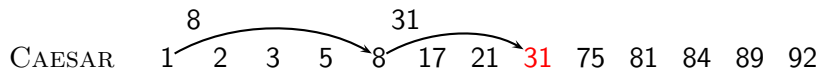
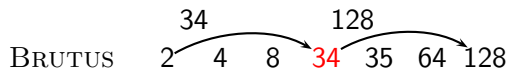
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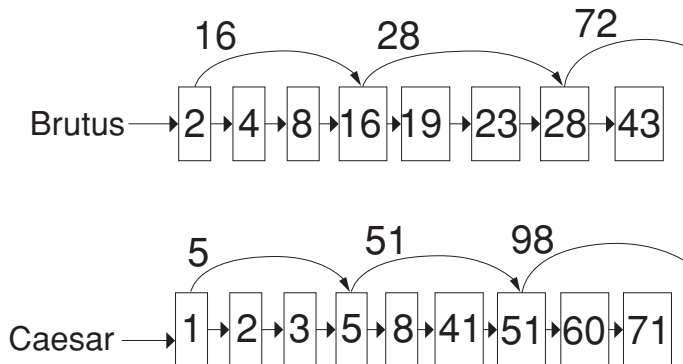
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Skip lists: Larger example



Intersecting with skip pointers

INTERSECTWITHSKIPS(p_1, p_2)

```
1  answer  $\leftarrow \langle \rangle$ 
2  while  $p_1 \neq \text{NIL}$  and  $p_2 \neq \text{NIL}$ 
3  do if  $\text{docID}(p_1) = \text{docID}(p_2)$ 
4      then  $\text{ADD}(\text{answer}, \text{docID}(p_1))$ 
5           $p_1 \leftarrow \text{next}(p_1)$ 
6           $p_2 \leftarrow \text{next}(p_2)$ 
7  else if  $\text{docID}(p_1) < \text{docID}(p_2)$ 
8      then if  $\text{hasSkip}(p_1)$  and  $(\text{docID}(\text{skip}(p_1)) \leq \text{docID}(p_2))$ 
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14         do  $p_2 \leftarrow \text{skip}(p_2)$ 
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16 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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- Two-word phrases can now easily be answered.

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- 4: $\langle 8, 16, 190, 429, 433 \rangle$;
- 5: $\langle 363, 367 \rangle$;
- 7: $\langle 13, 23, 191 \rangle$; ...

BE, 178239:

- 1: $\langle 17, 25 \rangle$;
- 4: $\langle 17, 191, 291, 430, 434 \rangle$;
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Positional indexes: Example

Query: *"to₁ be₂ or₃ not₄ to₅ be₆"*

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Document 4 is a match!

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- *Employment agencies that place healthcare workers are seeing growth* is a hit.
- *Employment agencies that have learned to adapt now place healthcare workers* is not a hit.

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- This is important for dynamic summaries etc.

“Proximity” intersection

```

POSITIONALINTERSECT( $p_1, p_2, k$ )
1   $answer \leftarrow \langle \rangle$ 
2  while  $p_1 \neq \text{NIL}$  and  $p_2 \neq \text{NIL}$ 
3  do if  $\text{docID}(p_1) = \text{docID}(p_2)$ 
4      then  $I \leftarrow \langle \rangle$ 
5           $pp_1 \leftarrow \text{positions}(p_1)$ 
6           $pp_2 \leftarrow \text{positions}(p_2)$ 
7          while  $pp_1 \neq \text{NIL}$ 
8              do while  $pp_2 \neq \text{NIL}$ 
9                  do if  $|\text{pos}(pp_1) - \text{pos}(pp_2)| \leq k$ 
10                     then  $\text{ADD}(I, \text{pos}(pp_2))$ 
11                     else if  $\text{pos}(pp_2) > \text{pos}(pp_1)$ 
12                         then break
13                      $pp_2 \leftarrow \text{next}(pp_2)$ 
14                     while  $I \neq \langle \rangle$  and  $|I[0] - \text{pos}(pp_1)| > k$ 
15                         do  $\text{DELETE}(I[0])$ 
16                     for each  $ps \in I$ 
17                         do  $\text{ADD}(answer, \langle \text{docID}(p_1), \text{pos}(pp_1), ps \rangle)$ 
18                      $pp_1 \leftarrow \text{next}(pp_1)$ 
19                  $p_1 \leftarrow \text{next}(p_1)$ 
20                  $p_2 \leftarrow \text{next}(p_2)$ 
21             else if  $\text{docID}(p_1) < \text{docID}(p_2)$ 
22                 then  $p_1 \leftarrow \text{next}(p_1)$ 
23             else  $p_2 \leftarrow \text{next}(p_2)$ 
24 return  $answer$ 

```

Combination scheme

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- 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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- For web search engines, positional queries are much more expensive than regular Boolean queries.
- 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?

Take-away

- Understanding of the basic unit of classical information retrieval systems: **words** and **documents**: What is a document, what is a term?
- Tokenization: how to get from raw text to words (or tokens)
- More complex indexes: skip pointers and phrases

Resources

- Chapter 2 of IIR
- Resources at <http://cislmu.org>
 - Porter stemmer
 - A fun number search on Google