Overview

- Introduction
- Hardware
- BSBI - Block sort-based indexing
- SPIMI - Single Pass in-memory indexing
- Distributed indexing
- Dynamic indexing
- Miscellaneous topics
**The index has a list of vector space models**

<table>
<thead>
<tr>
<th>Term</th>
<th>Frequency</th>
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<tbody>
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<td>1998</td>
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<td>1 Every</td>
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</tr>
<tr>
<td>1 wrote</td>
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**Letter from dead sister haunts brothers**

Every time Julie Jensen's brothers hear the letter read, it brings everything back. Most of all, they wonder if they could have saved her. Her husband now stands trial for allegedly killing her. "I pray I'm wrong + nothing happens," Julie wrote days before her 1998 death. full story
“Term-Document Matrix” Capture Keywords

A Column for Each Web Page (or “Document”)

- This picture is deceptive; it is really very sparse.
- Our queries are terms - not documents.
- We need to “invert” the vector space model.
- To make “postings”
Introduction

Terms

• Inverted index
Introduction

Terms

- Inverted index
- (Term, Document) pairs
Introduction

Terms

- Inverted index
- (Term, Document) pairs
- building blocks for working with Term-Document Matrices
Introduction

Terms

- Inverted index
- (Term, Document) pairs
- building blocks for working with Term-Document Matrices
- Index construction (or indexing)
Terms

- **Inverted index**
  - (Term, Document) pairs
  - building blocks for working with Term-Document Matrices
- **Index construction (or indexing)**
  - The process of building an inverted index from a corpus
Introduction

Terms

- Inverted index
- (Term, Document) pairs
- building blocks for working with Term-Document Matrices
- Index construction (or indexing)
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- Indexer
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Terms

- Inverted index
- (Term, Document) pairs
- building blocks for working with Term-Document Matrices
- Index construction (or indexing)
- The process of building an inverted index from a corpus
- Indexer
- The system architecture and algorithm that constructs the index
The index is built from term-document pairs

**Indices**

**Letter from dead sister haunts brothers**

Every time Julie Jensen's brothers hear the letter read, it brings everything back. Most of all, they wonder if they could have saved her. Her husband now stands trial for allegedly killing her. "I pray I'm wrong + nothing happens," Julie wrote days before her 1998 death. full story

**(TERM, DOCUMENT)**

(Every, www.cnn.com)
(Her, www.cnn.com)
(I, www.cnn.com)
(I'm, www.cnn.com)
(Jensen's, www.cnn.com)
(Julie, www.cnn.com)
(Most, www.cnn.com)
(all, www.cnn.com)
(allegedly, www.cnn.com)
(back, www.cnn.com)
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(wrote, www.cnn.com)
The index is built from term-document pairs

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<tr>
<td>haunts</td>
<td></td>
</tr>
</tbody>
</table>
The index is built from term-document pairs

- Core indexing step is to sort by terms
Term-document pairs make lists of postings

(TERM, DOCUMENT, DOCUMENT, DOCUMENT, ....)
(Every, www.cnn.com, news.bbc.co.uk)
(Her, www.cnn.com, news.google.com)
(Jensen's, www.cnn.com)
(Julie, www.cnn.com)
(Most, www.cnn.com)
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Term-document pairs make lists of postings

- A posting is a list of all documents in which a term occurs.

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Term-document pairs make lists of postings

A posting is a list of all documents in which a term occurs.

This is “inverted” from how documents naturally occur.

(TERM, DOCUMENT, DOCUMENT, DOCUMENT, ....)
(Every, www.cnn.com, news.bbc.co.uk)
(Her, www.cnn.com, news.google.com)
(Jensen's, www.cnn.com)
(Julie, www.cnn.com)
(Most, www.cnn.com)
(all, www.cnn.com)
(allegedly, www.cnn.com)
Terms

- How do we construct an index?
Interactions

- An indexer needs raw text
- We need crawlers to get the documents
- We need APIs to get the documents from data stores
- We need parsers (HTML, PDF, PowerPoint, etc.) to convert the documents
- Indexing the web means this has to be done web-scale
Construction

- Index construction in main memory is simple and fast.
- But:
  - As we build the index we parse docs one at a time
  - Final postings for a term are incomplete until the end.
  - At 10-12 postings per term, large collections demand a lot of space
  - Intermediate results must be stored on disk
Overview

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- Hardware
- BSBI - Block sort-based indexing
- SPIMI - Single Pass in-memory indexing
- Distributed indexing
- Dynamic indexing
- Miscellaneous topics
System Parameters

- Disk seek time = 0.005 sec
- Transfer time per byte = 0.00000002 sec
- Processor clock rate = 0.00000001 sec
- Size of main memory = several GB
- Size of disk space = several TB
System Parameters

- **Disk Seek Time**
  - The amount of time to get the disk head to the data
  - About 10 times slower than memory access
  - We must utilize caching
  - No data is transferred during seek

- Data is transferred from disk in **blocks**
  - There is no additional overhead to read in an entire block
    - 0.2 seconds to get 10 MB if it is one block
    - 0.7 seconds to get 10 MB if it is stored in 100 blocks
System Parameters

• Data is transferred from disk in blocks
• Operating Systems read data in blocks, so
• Reading one byte and reading one block take the same amount of time
System Parameters

- Data transfers are done on the system bus, not by the processor
- The processor is not used during disk I/O
- Assuming an efficient decompression algorithm
  - The total time of reading and then decompressing compressed data is usually less than reading uncompressed data.
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Reuters collection example (approximate #’s)

- 800,000 documents from the Reuters news feed
- 200 terms per document
- 400,000 unique terms
- number of postings 100,000,000

**Extreme conditions create rare Antarctic clouds**

SYDNEY (Reuters) - Rare, mother-of-pearl colored clouds caused by extreme weather conditions above Antarctica are a possible indication of global warming, Australian scientists said on Tuesday.

Known as nacreous clouds, the spectacular formations showing delicate wisps of colors were photographed in the sky over an Australian meteorological base at Mawson Station on July 25.
Reuters collection example (approximate #’s)
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- Sorting 100,000,000 records on disk is too slow because of disk seek time.
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  - Then by document in each term
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• Parse and build posting entries one at a time
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• Doing this with random disk seeks is too slow
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  • Parse and build posting entries one at a time
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  • e.g. If every comparison takes 2 disk seeks and N items need to be sorted with N \( \log_2(N) \) comparisons?
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- Parse and build posting entries one at a time
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  - Then by document in each term
- Doing this with random disk seeks is too slow
- e.g. If every comparison takes 2 disk seeks and N items need to be sorted with $N \log_2(N)$ comparisons?
  - 306ish days?
Reuters collection example (approximate #'s)
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- 100,000,000 records
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- $N \log_2(N)$ is $= 2,657,542,475.91$ comparisons
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- 2 disk seeks per comparison $= 13,287,712.38$ seconds $\times 2$
Reuters collection example (approximate #'s)

- 100,000,000 records
- $N \log_2 N$ is $2,657,542,475.91$ comparisons
- 2 disk seeks per comparison = $13,287,712.38$ seconds x 2
- = $26,575,424.76$ seconds
Reuters collection example (approximate #'s)

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- $= 26,575,424.76$ seconds
- $= 442,923.75$ minutes
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- = $84\%$ of a year
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- 2 disk seeks per comparison = 13,287,712.38 seconds x 2
  - = 26,575,424.76 seconds
  - = 442,923.75 minutes
  - = 7,382.06 hours
  - = 307.59 days
  - = 84% of a year
  - = 1% of your life
Different way to sort index

- 12-byte records (term, doc, meta-data)
- Need to sort $T=100,000,000$ such 12-byte records by term
- Define a block to have 1,600,000 such records
  - can easily fit a couple blocks in memory
- we will be working with 64 such blocks
- Accumulate postings for each block (real blocks are bigger)
- Sort each block
- Write to disk
- Then merge
BSBI - Block sort-based indexing

Different way to sort index

Block
(Every, www.cnn.com)
(Her, news.google.com)
(I'm, news.bbc.co.uk)

Block
(1998, news.google.com)
(Her, news.bbc.co.uk)
(I, www.cnn.com)
(Jensen's, www.cnn.com)

Merged Postings
(1998, news.google.com)
(Every, www.cnn.com)
(Her, news.bbc.co.uk)
(Her, news.google.com)
(I, www.cnn.com)
(I'm, news.bbc.co.uk)
(Jensen's, www.cnn.com)

Disk
BlockSortBasedIndexConstruction()
1  $n \leftarrow 0$
2  while (all documents not processed)
3    do $block \leftarrow \text{ParseNextBlock}()$
4    BSBI-Invert($block$)
5    WriteBlockToDisk($block$, $f_n$)
6    MergeBlocks($f_1$, $f_2$, ..., $f_n$, $f_{\text{merged}}$)
BSBI - Block sort-based indexing

Block merge indexing

• Parse documents into (TermID, DocID) pairs until “block” is full

• Invert the block
  • Sort the (TermID, DocID) pairs
  • Compile into TermID posting lists

• Write the block to disk

• Then merge all blocks into one large postings file
  • Need 2 copies of the data on disk (input then output)
Analysis of BSBI

- The dominant term is $O(T \log T)$
  - $T$ is the number of TermID,DocID pairs
- But in practice ParseNextBlock takes the most time
- Then MergingBlocks
- Again, disk seeks times versus memory access times