THE UNIVERSITY of EDINBURGH

Text Technologies for Data Science

INFR11145

Indexing (2)

Instructor:
Walid Magdy

02-Oct-2024

1

Lecture Objectives

- Learn more about indexing:
  - Structured documents
  - Extent index
  - Index compression
- Data structure
- Wild-char search and applications

** You are not asked to implement any of the content in this lecture, but you might think of using some for your course project ☺*

Walid Magdy, TTDS 2024/2025

THE UNIVERSITY of EDINBURGH

2

Structured Documents

- Document are not always flat:
  - Meta-data: title, author, time-stamp
  - Structure: headline, section, body
  - Tags: link, hashtag, mention
- How to deal with it?
  - Neglect!
  - Create separate index for each field
  - Use “extent index”

Extent Index

- Special “term” for each element/field/tag
  - Index all terms in a structured document as plain text
  - Terms in a given field/tag get special additional entry
  - Posting: spans of window related to a given field
  - Allows multiple overlapping spans of different types

he	1,1	1,5	2,1	3,3	4,3	5,1	
drink	1,8	2,4	2,6	2,8	3,6	4,5	5,6
ink	3,8	4,2	5,8				
pink	4,8	5,7					
Link	3,1:2	4,1:4	5,7:8				

D1: He likes to wink, he likes to drink

D2: He likes to drink, and drink, and drink

D3: The thing he likes to drink is ink

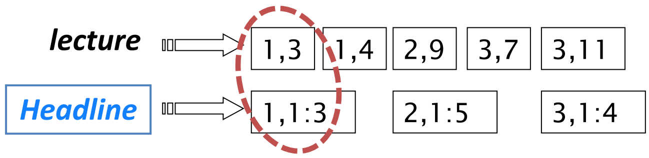
D4: The ink he likes to drink is pink

D5: He likes to wink, and drink pink ink

Using Extent

- Doc: 1 →
  Headline: "*Information retrieval lecture*" (1, 2, 3)
  Text: "~~*this is*~~ *lecture 6* ~~*of the*~~ *TTDS course* ~~*on*~~ *IR*" (4, 5, 6, 7, 8)

- Query → Headline: lecture



Walid Magdy, TTDS 2024/2025

THE UNIVERSITY *of* EDINBURGH

5

Index Compression

- Inverted indices are big
  - Large disk space → large I/O operations
- Index compression
  - Reduce space → less I/O
  - Allow more chunks of index to be cached in memory
- Large size goes to:
  - terms? document numbers?
  - Ideas:
    - Compress document numbers, how?

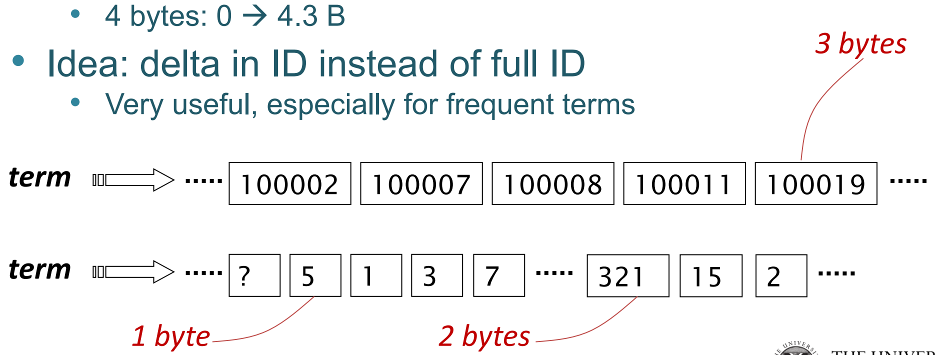
Walid Magdy, TTDS 2024/2025

THE UNIVERSITY *of* EDINBURGH

6

Delta Encoding

- Large collections → large sequence of doc IDs
  - e.g. Doc IDs: 1, 2, 3, … 66,032, ……, 5,323,424,235
- Large ID number → more bytes to store
  - 1 byte: 0→255
  - 2 bytes: 0 → 65,535
  - 4 bytes: 0 → 4.3 B
- Idea: delta in ID instead of full ID
  - Very useful, especially for frequent terms



THE UNIVERSITY of EDINBURGH

7

v-byte Encoding

- Have different byte storage for each delta in index
  - Use fewer bits to encode
  - High bit in a byte → 1/0 = terminate/continue
  - Remaining 7 bits → binary number
  - Examples:
    - "6" → **1**0000110
    - "127" → **1**1111111
    - "128" → 0000001 0000000
- Real example sequence:

10000101**0**0000000**1**1000001**0**1**1**0000111

→ →

THE UNIVERSITY of EDINBURGH

8

Index Compression

- There are more sophisticated compression algorithms:
  - Elias gamma code
- The more compression
  - Less storage
  - More processing
- In general
  - Less I/O + more processing > more I/O + no processing
    ">" = faster
  - With new data structures, problem is less severe

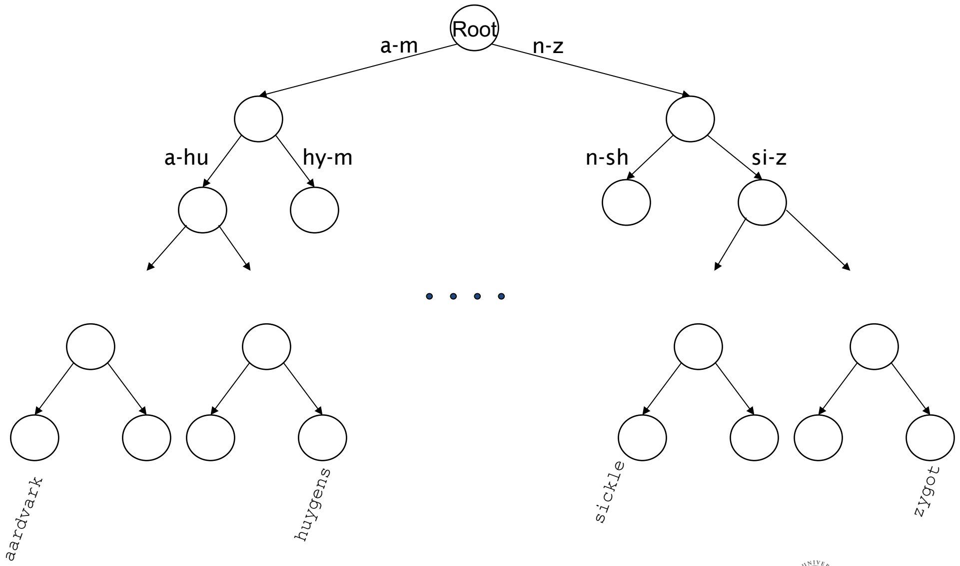
Dictionary Data Structures

- The dictionary data structure stores the term vocabulary, document frequency, pointers to each postings list …
- For small collections, load full dictionary in memory. In real-life, cannot load all index to memory!
  - Then what to load?
  - How to reach quickly?
  - What data structure to use for inverted index?

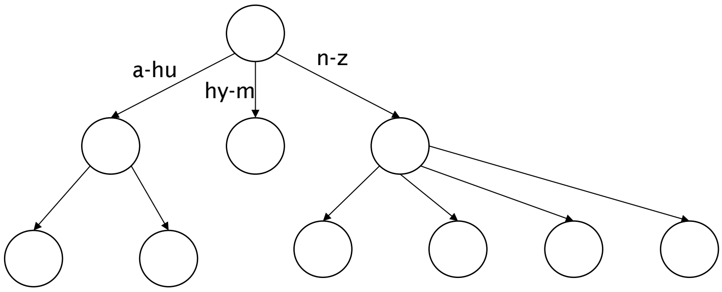
Hashes

- Each vocabulary term is hashed to an integer
- Pros
  - Lookup is faster than for a tree: O(1)
- Cons
  - No easy way to find minor variants:
    - judgment/judgement
  - No prefix search
  - If vocabulary keeps growing, need to occasionally do the expensive operation of rehashing everything

Trees: Binary Search Tree



Trees: B-tree



Every internal node has a number of children in the interval [a,b] where a, b are appropriate natural numbers, e.g., [2,4].

Trees

- Pros?
  - Solves the prefix problem (terms starting with “ab”)
- Cons?
  - Slower: O(log M) [and this requires balanced tree]
  - Rebalancing binary trees is expensive
    - But B-trees mitigate the rebalancing problem

Wild-Card Queries: *

- mon*: find all docs containing any word beginning "mon".
- Easy with binary tree (or B-tree) lexicon
- *mon: find words ending in "mon": harder
  - Maintain an additional B-tree for terms backwards.
- How can we enumerate all terms meeting the wild-card query pro*cent ?
- Query processing: se*ate AND fil*er ?
  - Expensive

THE UNIVERSITY of EDINBURGH

15

Permuterm Indexes

- Transform wild-card queries so that the * occurs at the end
- For term *hello*, index under:
  - hello$, ello$h, llohe, lohel, o$hell, $hello
    where $ is a special symbol.
- Rotate query wild-card to the end
- Queries:
  - X lookup on X$
  - X* lookup on $X*
  - *X lookup on
  - X*Y lookup on
- Index Size?

THE UNIVERSITY of EDINBURGH

16

Character n-gram Indexes

- Enumerate all n-grams (sequence of *n* chars) occurring in any term
  - e.g., from text "*April is the cruelest month*" we get the 2-grams (bigrams) → a,ap,pr,ri,il,l,i,is,s,t,th,he,e,c,cr,ru,ue,el,le,es,st,t, m,mo,on,nt,h
  - $ is a special word boundary symbol
- Maintain a second inverted index from bigrams to dictionary terms that match each bigram.
  - Character n-grams → terms
  - terms → documents

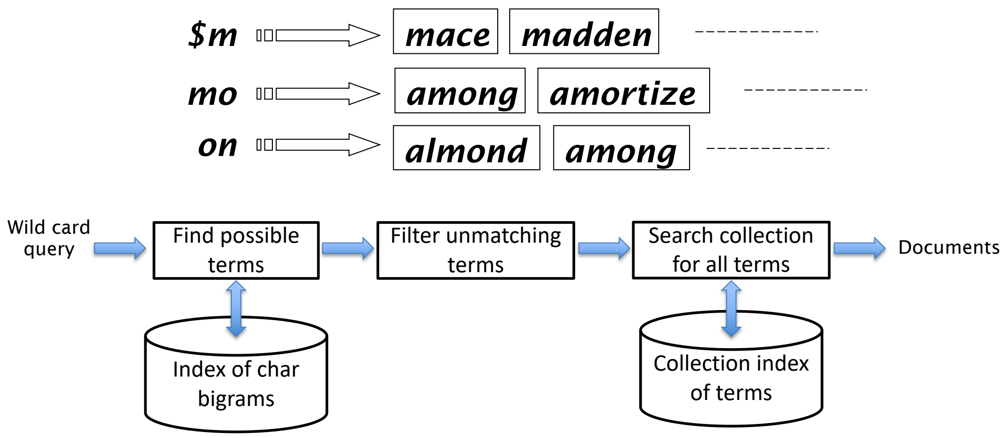
Walid Magdy, TTDS 2024/2025

THE UNIVERSITY of EDINBURGH

17

Character n-gram Indexes

- The *n*-gram index finds *terms* based on a query consisting of *n*-grams (here *n*=2).



Walid Magdy, TTDS 2024/2025

THE UNIVERSITY of EDINBURGH

18

Character n-gram Indexes: Query time

- *Step 1*: Query **mon*** → **$m** AND **mo** AND **on**
  - It would still match **moon**.
- *Step 2*: Must post-filter these terms against query.
  - Phrase match, or post-step1 match
- *Step 3*: Surviving enumerated terms are then looked up in the term-document inverted index.
  → **Montreal** OR **monster** OR **monkey**
- Wild-cards can result in expensive query execution (very large disjunctions…)

Walid Magdy, TTDS 2024/2025

THE UNIVERSITY of EDINBURGH

19

Character n-gram Indexes: Applications

- Spelling Correction
  - Create n-gram representation for words
  - Build index for words:
    - Dictionary of words → documents (each word is a document)
    - Character n-grams → terms
  - When getting a search term that is misspelled (OOV or not frequent), find possible corrections
    - Possible corrections = most matching results

Query: elepgant → $e el le ep pg ga an nt t$
Results:
elegant → $e el le eg ga an nt t$
elephant → $e el le ep ph ha an nt t$

Walid Magdy, TTDS 2024/2025

THE UNIVERSITY of EDINBURGH

20

Character n-gram Indexes: Applications

- Char n-grams can be used as direct index terms for some applications:
  - Arabic IR, when no stemmer/segmenter is available
  - Documents with spelling mistakes: OCR documents
- Word char representation can by with multiple n's
  - "elephant" → 2/3-gram →
    "$e el le ep ph ha an nt t$ $el $ele lep eph pha han ant nt$"

The **children** behaved well	**الأبناء** تصرفوا جيدا	$ا ال لأ أب بن نا اء ء$
Her **children** are cute	**أبناءها** لطاف	$أ أب بن نا اء ءه ها ا$

Document: Elepbant → $e el le ep pb ba an nt t$

Query: Elephant → $e el le ep ph ha an nt t$

Summary

- Index can by multilayer
  - Extent index (multi-terms in one position in document)
- Index does not have to be formed of words
  - Character n-grams representation of words
- Two indexes are sometimes used
  - Index of character n-grams to find matching words
  - Index of terms to search for matched words

Resources

- Text book 1: Intro to IR, Chapter 3.1 – 3.4
- Text book 2: IR in Practice, Chapter 5