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Text Technologies for Data Science

INFR11145

Indexing (2)

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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 ☺*

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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

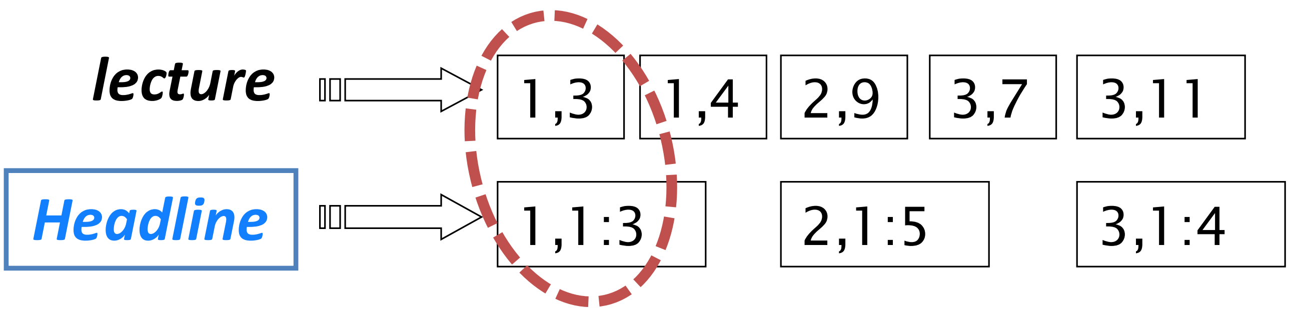
D4: The ink he likes to drink is pink

D5: He likes to wink, and drink pink ink

Using Extent

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

- Query → Headline: lecture

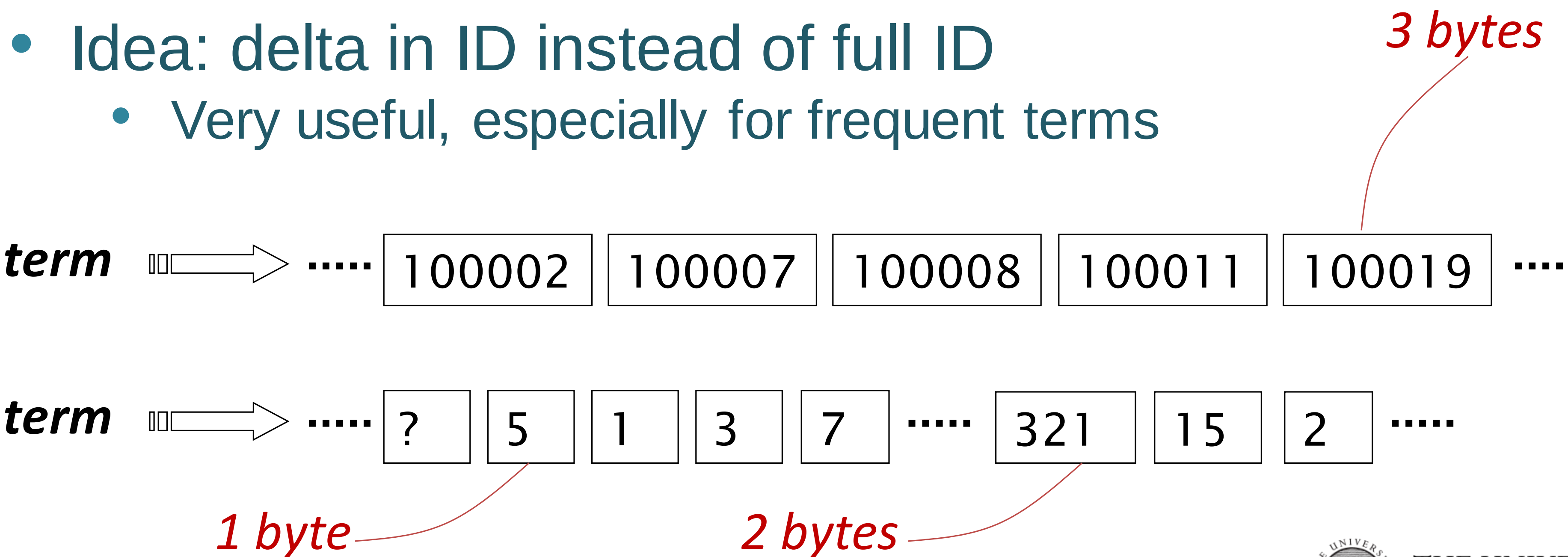


Index Compression

- 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?

Delta Encoding

- Large collections → large sequence of doc IDs
- 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



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" → ~~0~~0000001~~1~~0000000
- Real example sequence:

10000101**0**0000001**1**0000010**1**0000111

0000101 → 00000010000010 → 0000111

5 → **130** → **7**

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

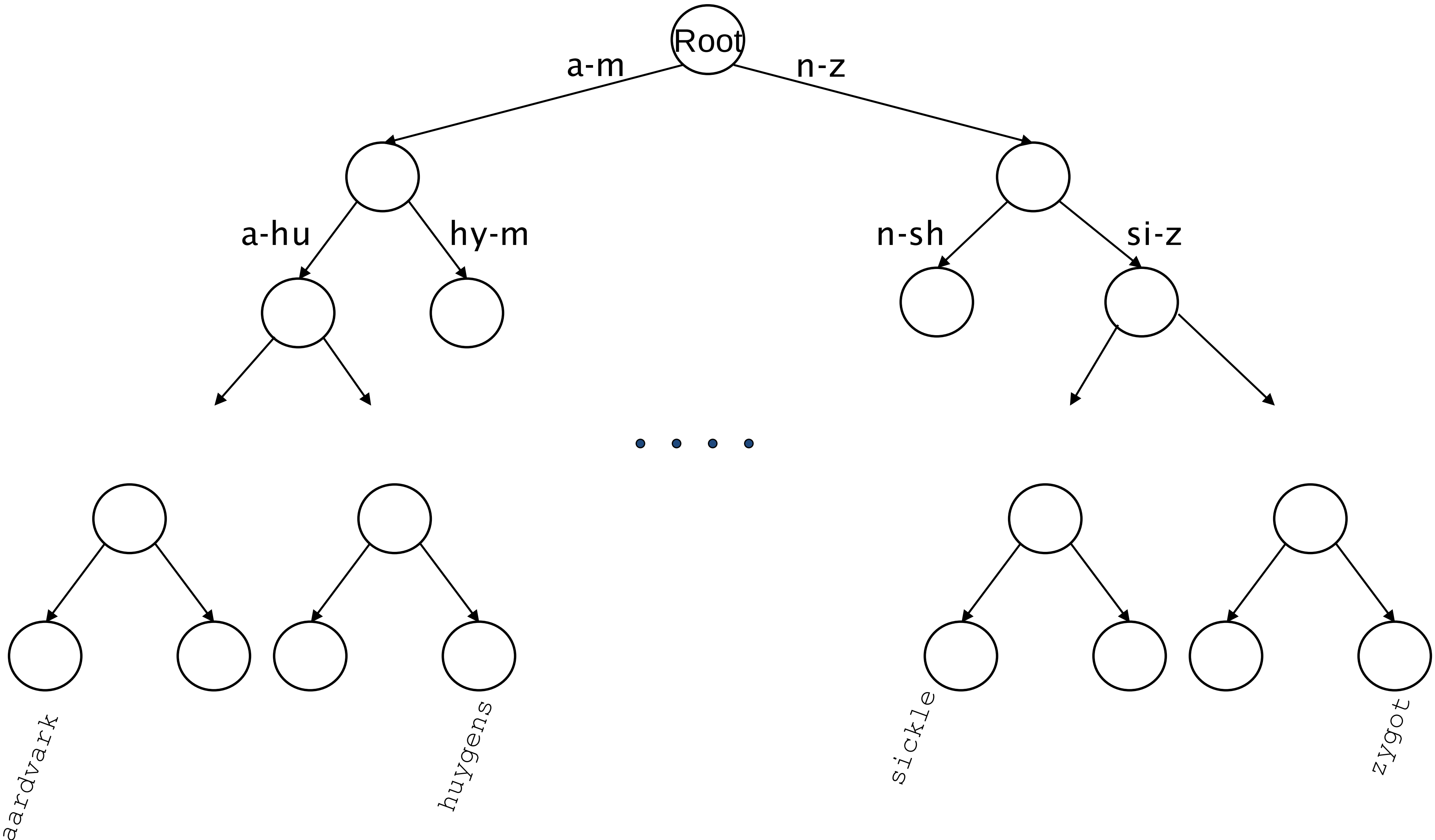
Dictionary Data Structures

- 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



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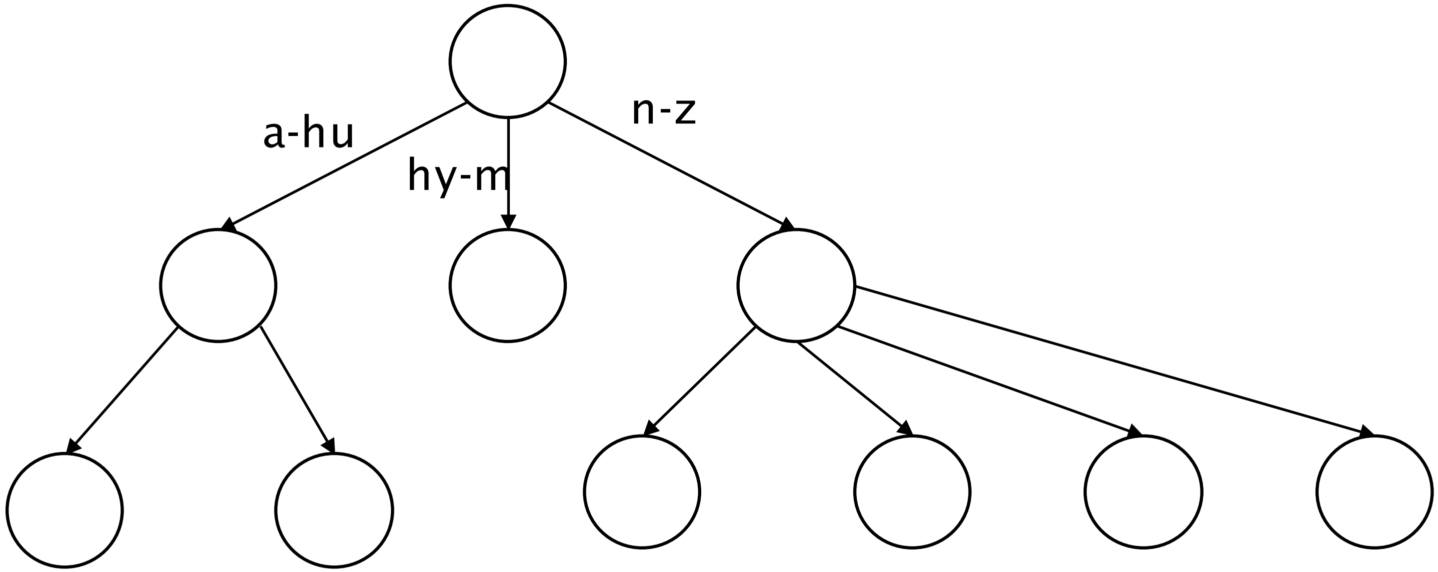
Trees: B-tree



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

Permuterm Indexes

- Transform wild-card queries so that the *s occur 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 right
- Queries:
    - X lookup on X$
    - X* lookup on $X*
    - *X lookup on X$*
    - X*Y lookup on Y$X*
- Index Size?

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
  - Words → documents

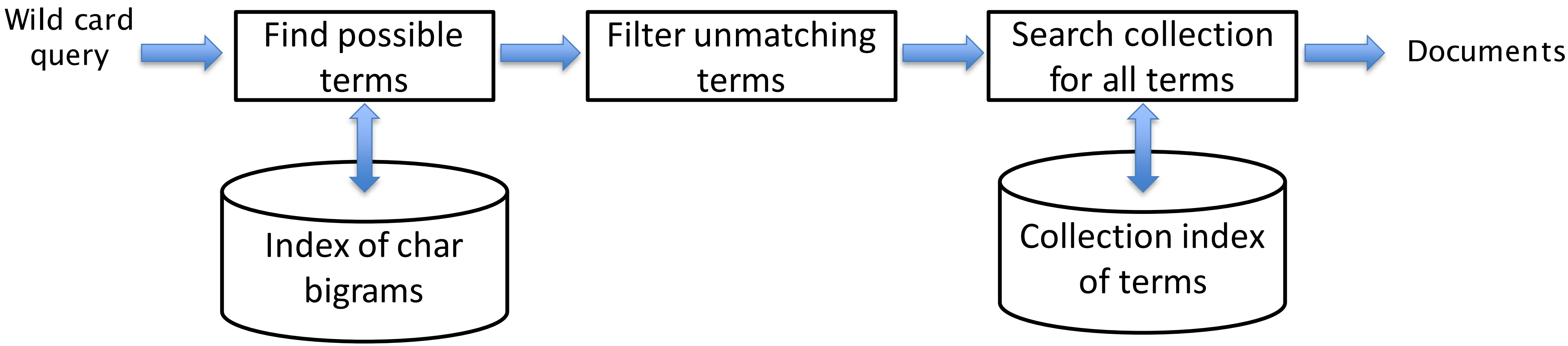
Character n-gram Indexes

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

$m → ***mace*** → ***madden*** → ...

mo → ***among*** → ***amortize*** → ...

on → ***almond*** → ***among*** → ...



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…)

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 → $e el le ep ph ha an nt t$

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 → $e el le ep ph ha an nt t$

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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