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Information Retrieval

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For me, data compression is more than a manipulation of numbers; it is the process of discovering structures that exist in the data**.**
– Khalid Sayood, University of Nebraska.

Agenda

- Statistic properties of terms
  - The rule of 30
  - Heap’s Law
  - Zipf’s Law
- Index Compression
  - Compressing Dictionaries
  - Compressing Postings

Index Compression

The Rule of 30

The 30 most common words account for 30% of the tokens in written text.

Add a, an, the, … to the stop words list.

Quiz

Given a collection (of documents), how to estimate the number of terms?

One (bad) Approach

- Use Oxford Dictionary
  - Oxford English Dictionary defines 600K+ words.
- The Problem
  - Does not contain people, places, products which users may query.

Heap's Law

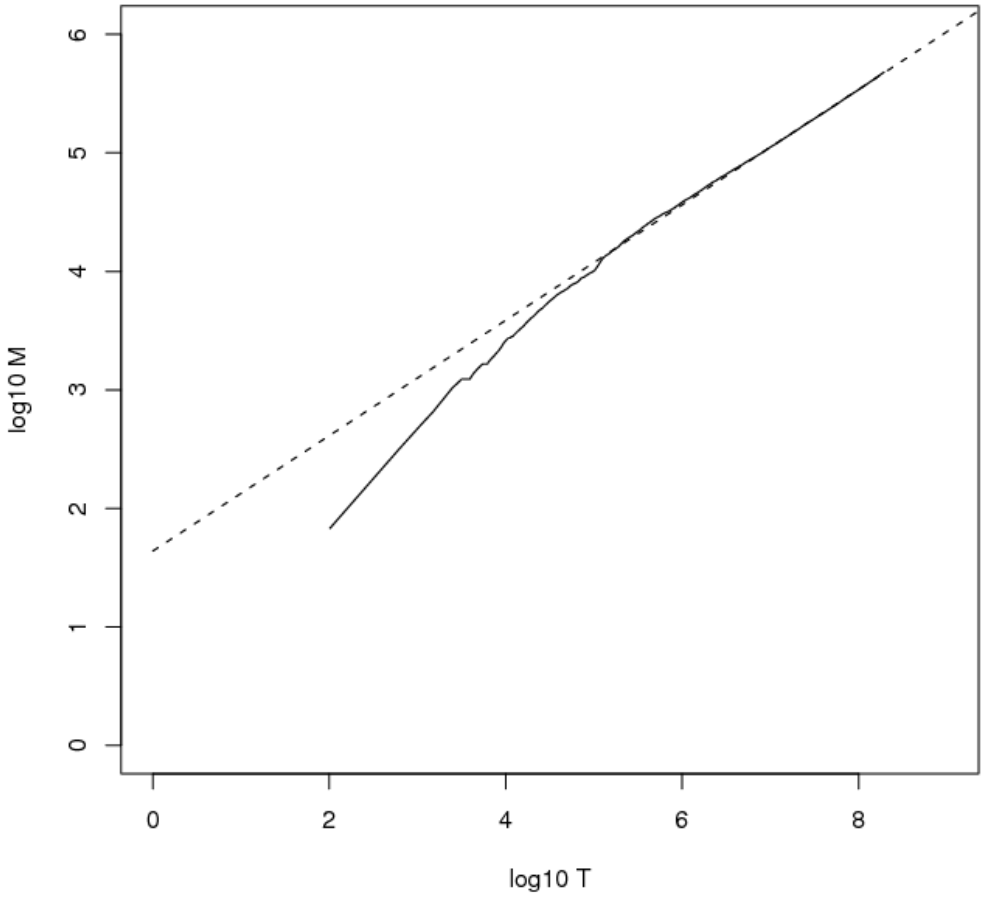
- An Empirical Finding (from experiments on several datasets)

$$M = kT^b$$

- M is the size of the vocabulary; T is the number of tokens in the collection

Heap's Law

- $\log_{10} M = 0.49 \log_{10} T + 1.64$ is the best least squares fit for RCV1.
- So $k = 10^{1.64} \approx 44$ and $b = 0.49$.
- For first 1,000,020 tokens, law predicts 38,323 terms.
- Actually, we have 38,365 terms.



Takeaways from Heap's Law

- Dictionary Size grows with collection size.
- Size of dictionary can get "really" large!

Term Frequency

- What are top-3 frequent terms in the text given below? Give the frequency of those terms.

Being an excellent student has more benefits than just getting good grades. In the short term, it will make you a more appealing college candidate and, in many cases, can earn you some fairly hefty scholarships. Big picture, the skills you learn at school will stick with you for the rest of your life, helping you tackle any problem that comes your way.

Repeating Terms

- Give me the term frequency for each repeating term.

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Repeating Tokens are Highlighted

- you = 5, the = 3, in = 2, your = 2 (case-folded)

You, being an excellent student have more benefits than just getting good grades. In the short term, it will make you a more appealing college candidate and, in many cases, can earn you some fairly hefty scholarships. Big picture, the skills you learn at school will stick with you for the rest of your life, helping you tackle any problem that comes your way.

Zipf's Law

The i^{th} most frequent term has frequency proportional to $\frac{1}{i}$

Do not apply on small examples…

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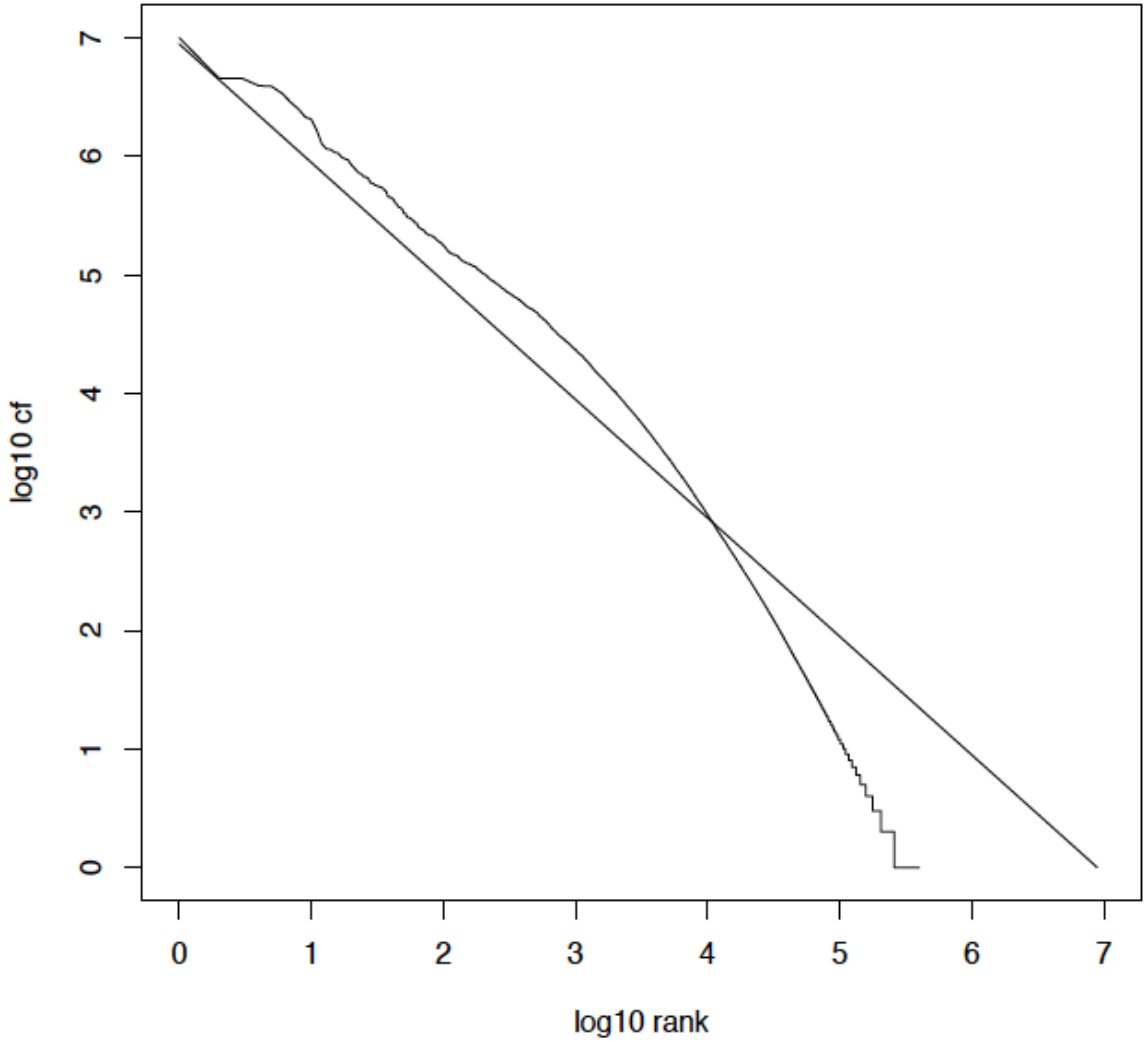
Only for illustration.

Rank	Frequency
1 (you)	6
2 (the)	3
3 (in)	2

$cf_i \propto 1/i = k/i$

k = 6 in our case!

Zipf's law for Reuters RCV1



Compressing Dictionaries

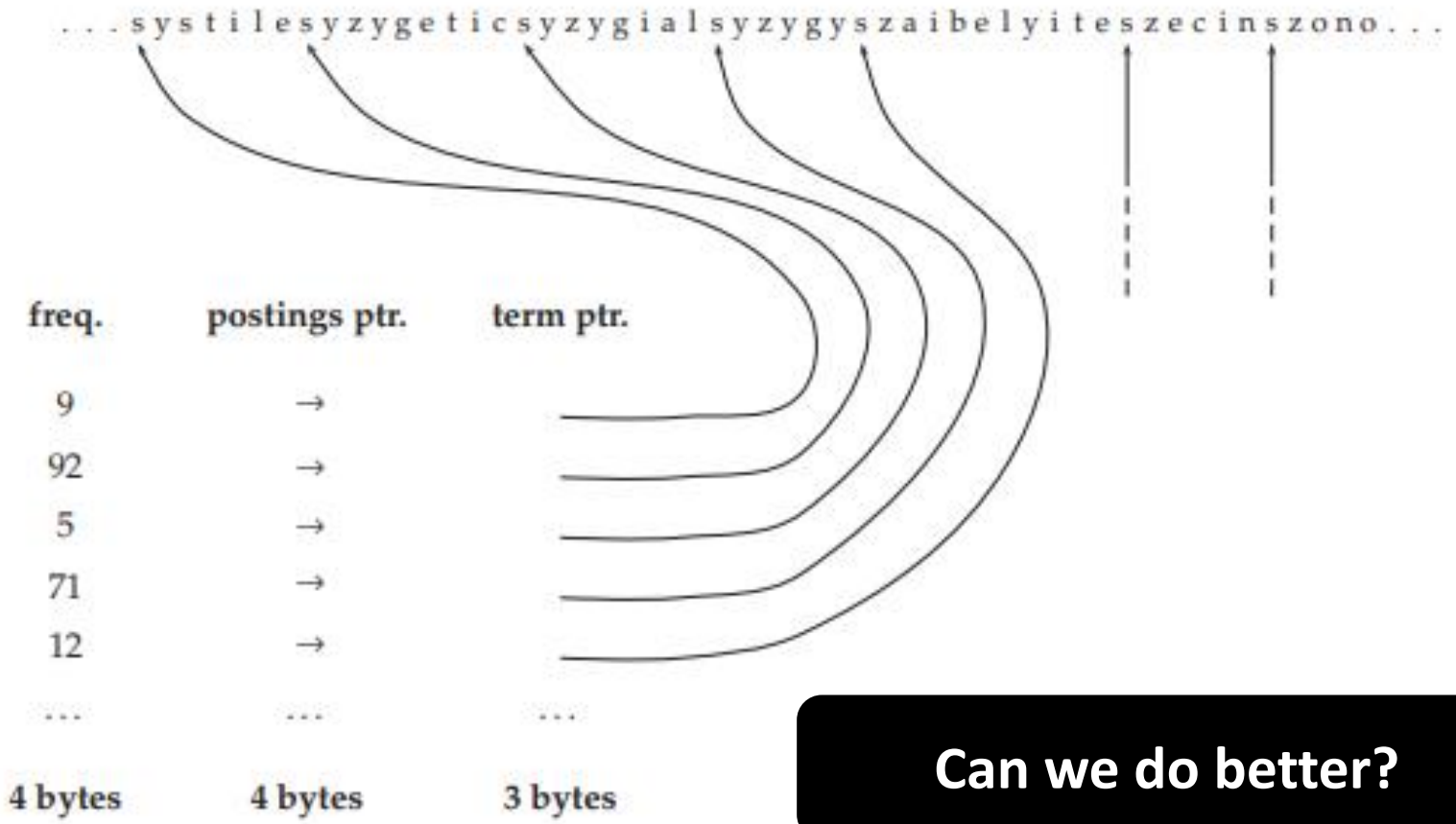
Dictionary as a Sorted Array

term	document frequency	pointer to postings list
a	656,265	⟶
aachen	65	⟶
…	…	…
zulu	221	⟶
20 bytes	4 bytes	4 bytes

Apply binary search to search the term array!

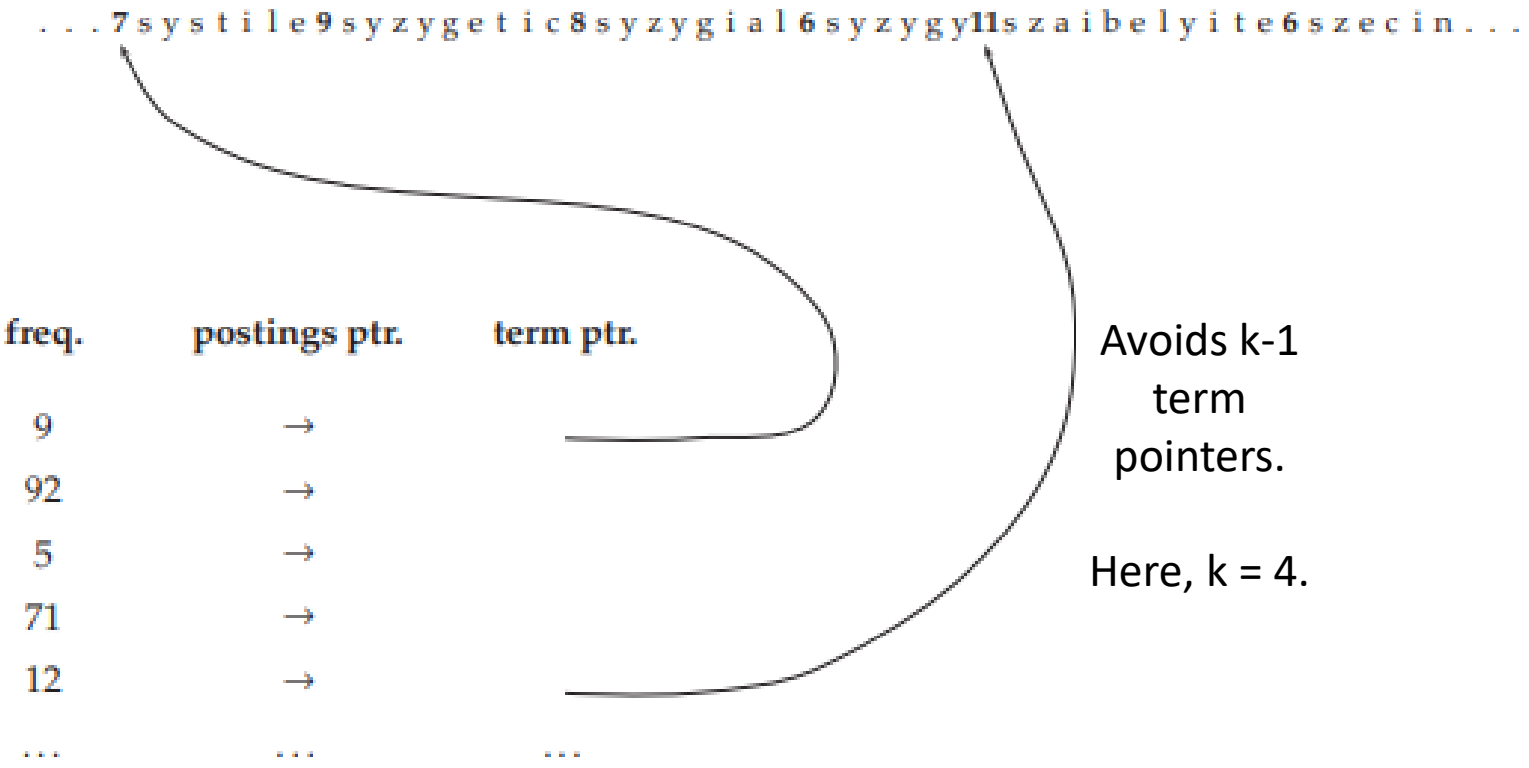
Can we do better?

Dictionary as a String



Can we do better?

Blocked Storage



Can we do better?

Clue: Consecutive entries in an alphabetically sorted list (Dictionary) share common prefixes!

Front Coding

One block in blocked compression ($k = 4$) . . .
8automata8automate9automatic10automation

. . . further compressed with front coding.
8automat∗a1⋄e2 ⋄ ic3⋄ion

Can you front-code at k = 3, "interspecies","interstellar","interstate"?

12inter*species7◊stellar5◊state

or

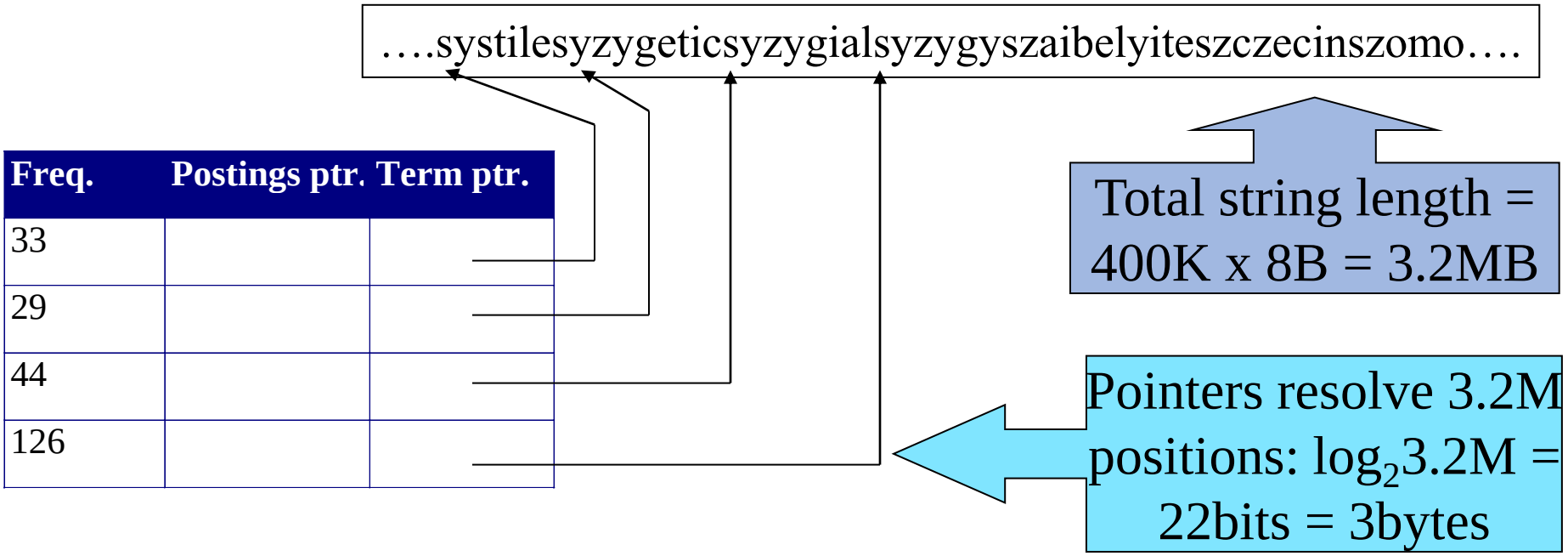
12inters*pecies6◊tellar4◊tate

Right Answer

- **12inters*pecies6◊tellar4◊tate**

Compressing the term list: Dictionary-as-a-String

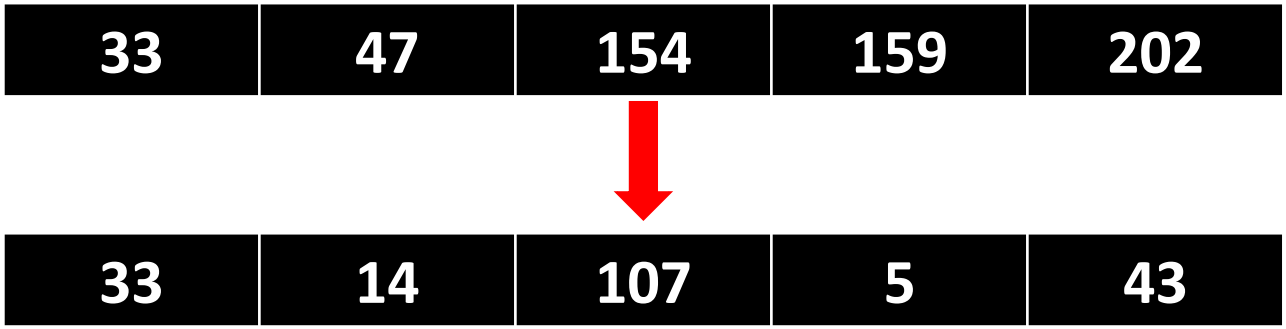
- Store dictionary as a (long) string of characters:
  - Pointer to next word shows end of current word
  - Hope to save up to 60% of dictionary space.



Compressing Postings

How to store a large number of "numbers" efficiently?

Store Gaps



Can we do better?

Clue: Smaller numbers can be represented using fewer bits.

Variable Byte Encoding

824	829	215406	…	…
824	5	214577	…	…

Gaps

<6, 56>	<5>	<13, 12, 49>	…	…

VBEncode

824 = 2^7 * 6 + 56. So, we use <56, 6> to represent it.
5 = 2^7 * 0 + 5. So, we use <5> to represent it.
214577 = 2^7 * ((2^7 * 13) + 12) + 49. So, <49,12,13>.

00000110 10111000 10000101 0001101 00001100 10110001 …

Encoded Bytestream

How to decode the bytestream?

00000110 10111000	10000101	0001101 00001100 10110001	…	…

Continuation bits are underlined.

Another Dig at 214577

- What is the VB encoding for 214577?

n	$\lfloor n/128 \rfloor$	$n \,\%\, 128$
214577	1676	49
1676	13	12
13	0	13

- So, 214577 = <13, 12, 49> which means ((13*128)+12)*128 + 49.
- Thus we have, 214577 represented as 0001101 00001100 10110001 in VB encoded bytestream.

Quiz

- Compute the variable byte codes for the postings list (100, 200, 400, 800)

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Postings

100	200	400	800

Gaps

100	100	200	400

Decomposing Gaps

n	$\lfloor n/128 \rfloor$	n % 128
100	0	100

n	$\lfloor n/128 \rfloor$	n % 128
200	1	72
1	0	1

n	$\lfloor n/128 \rfloor$	n % 128
400	3	16
3	0	3

VB Encoding

<100>	<100>	<1, 72>	<3, 16>

Result 11100100 11100100 00000001 11001000 000000011 10010000

Quiz

- Compute the variable byte codes for the postings list (100, 200, 400, 800)
- Answer: 11100100 11100100 00000001 11001000 000000011 10010000

Questions