Carnegie Mellon

15-826: Multimedia (Databases) and Data Mining

Lecture #13: Text - part II

Inversion; signature files

C. Faloutsos

Must-read Material

- MM Textbook, Chapter 6

Optional (but terrific to read)

- ★ McIlroy, M. D. (Jan. 1982). "Development of a Spelling List." IEEE Trans. on Communications COM-30(1): 91-99.
  - http://ieeexplore.ieee.org/document/1095395/
- ★ Severance, D. G. and G. M. Lohman (Sept. 1976). "Differential Files: Their Application to the Maintenance of Large Databases." ACM TODS 1(3): 256-267.
  - http://dl.acm.org/citation.cfm?id=320484

Outline

Goal: 'Find similar / interesting things'

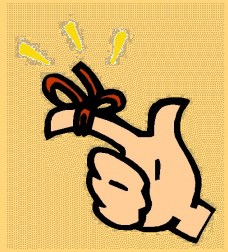
- Intro to DB
- Indexing - similarity search
  - Primary key
  - …
  - fractals
  - Text
  - …
- Data Mining

Text - Detailed outline

- text
  - problem
  - full text scanning
  - inversion
  - signature files
  - clustering
  - information filtering and LSI

Problem

- How to find doc's with "data mining"?

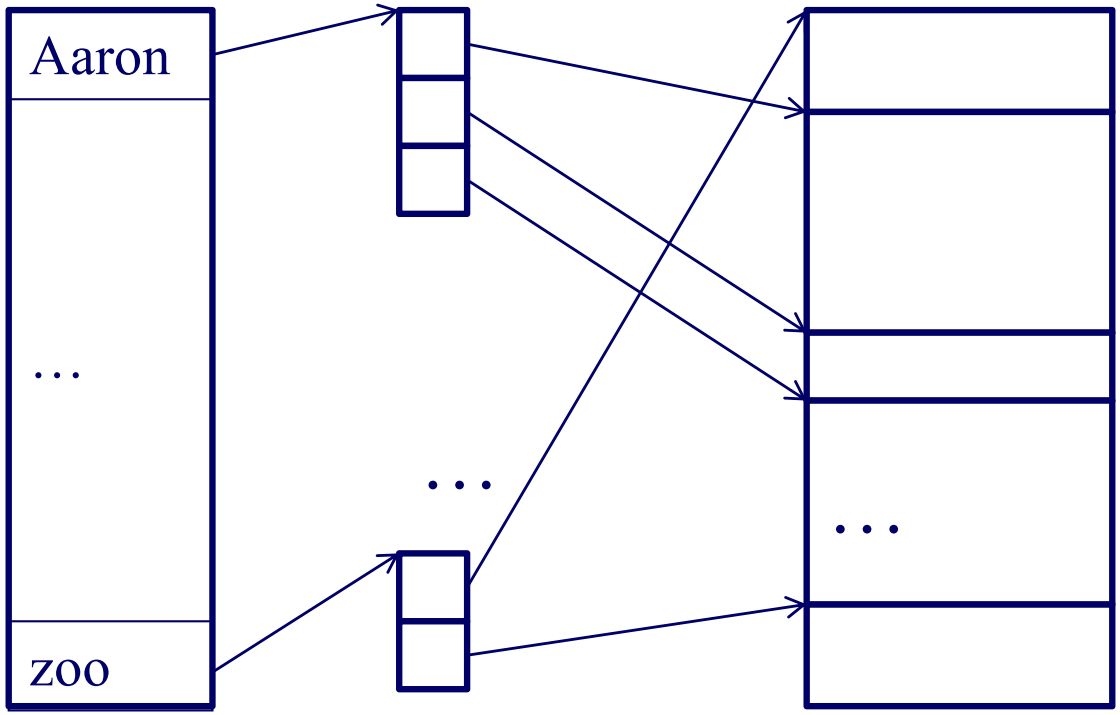


Conclusion

- How to find doc's with "data mining"?
- A1: full text scanning
  - A1.1: string editing distance
- A2: inversion
  - Elias Codes
- (A3: signature files – 'Bloom filters')

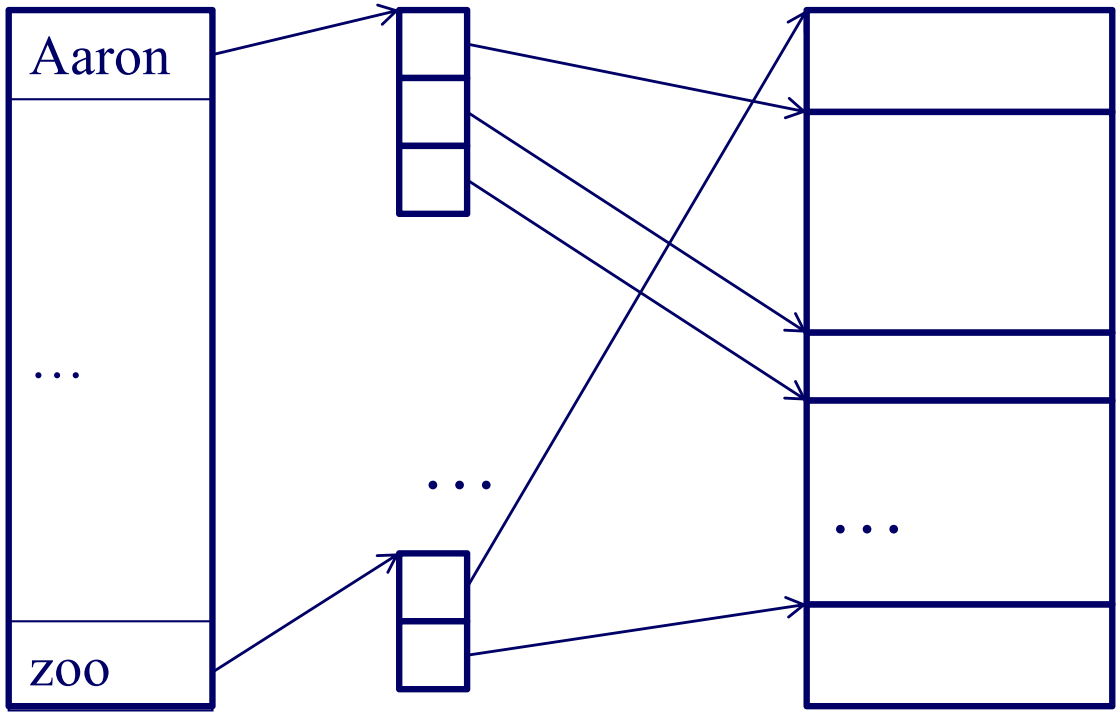
Text - Inversion

Dictionary Postings lists Text file



Text - Inversion

Dictionary Postings lists Text file



Q: space overhead?

Text - Inversion

- how to organize dictionary?

- stemming – Y/N?
- insertions?

Text - Inversion

- how to organize dictionary?
  - B-tree, hashing, TRIEs, PATRICIA trees, ...
- stemming – Y/N?
- insertions?

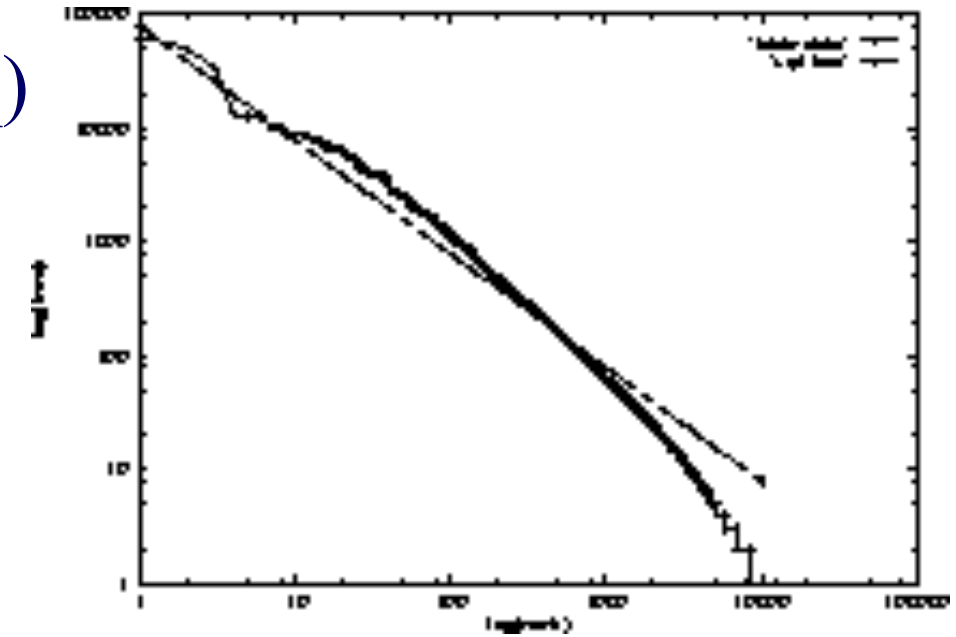
Text - Inversion

- variations:
- Parallelism [Tomasic+,93]
- Insertions [Tomasic+94], [Brown+]
  - 'zipf' distributions
- Approximate searching ('glimpse' [Wu+])

Text - Inversion

- postings list – more Zipf distr.: eg., rank-frequency plot of 'Bible'

log(freq)



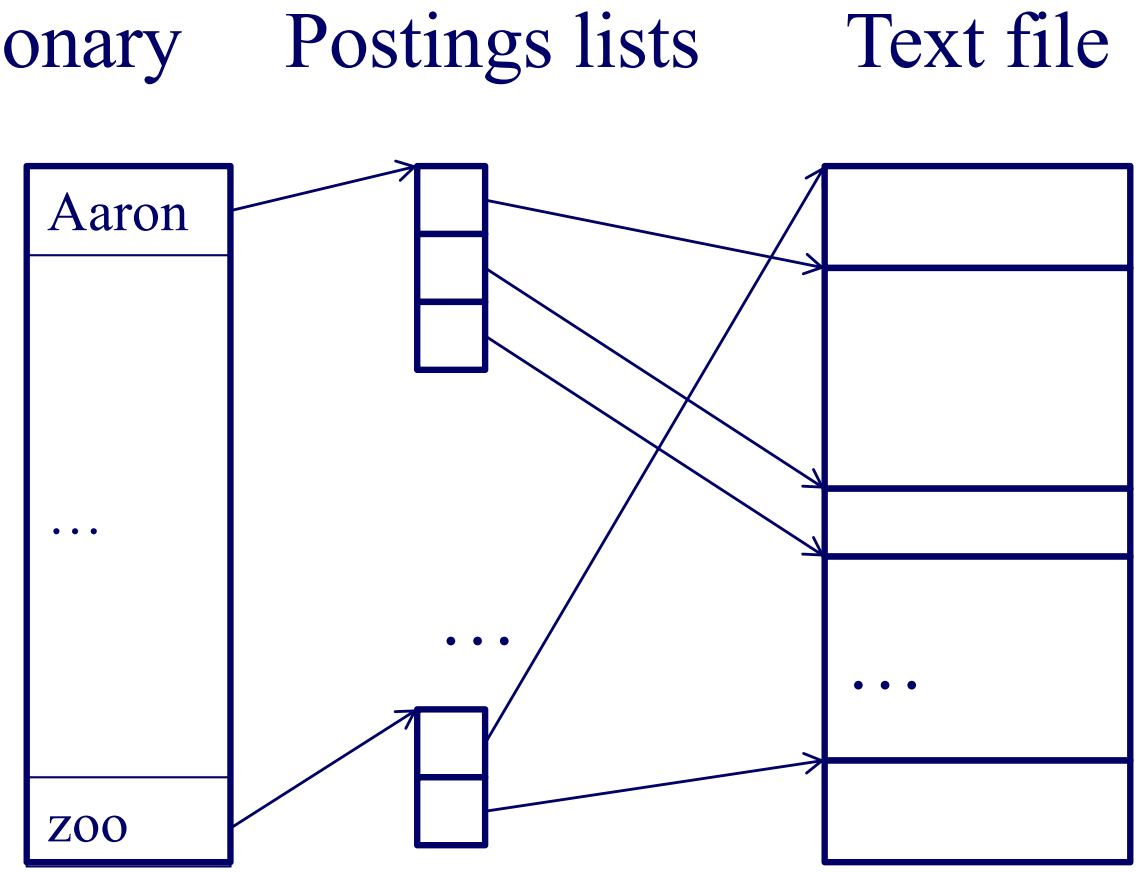
log(rank)

$$freq \approx \frac{1}{rank \ \ln(1.78V)}$$

Text - Inversion

- postings lists
  - Cutting+Pedersen
    - (keep first 4 in B-tree leaves)
  - how to allocate space: [Faloutsos+92]
    - geometric progression
  - compression (Elias codes) [Zobel+] – down to 2% overhead!
  - Compression and doc reordering [Blandford+2002]

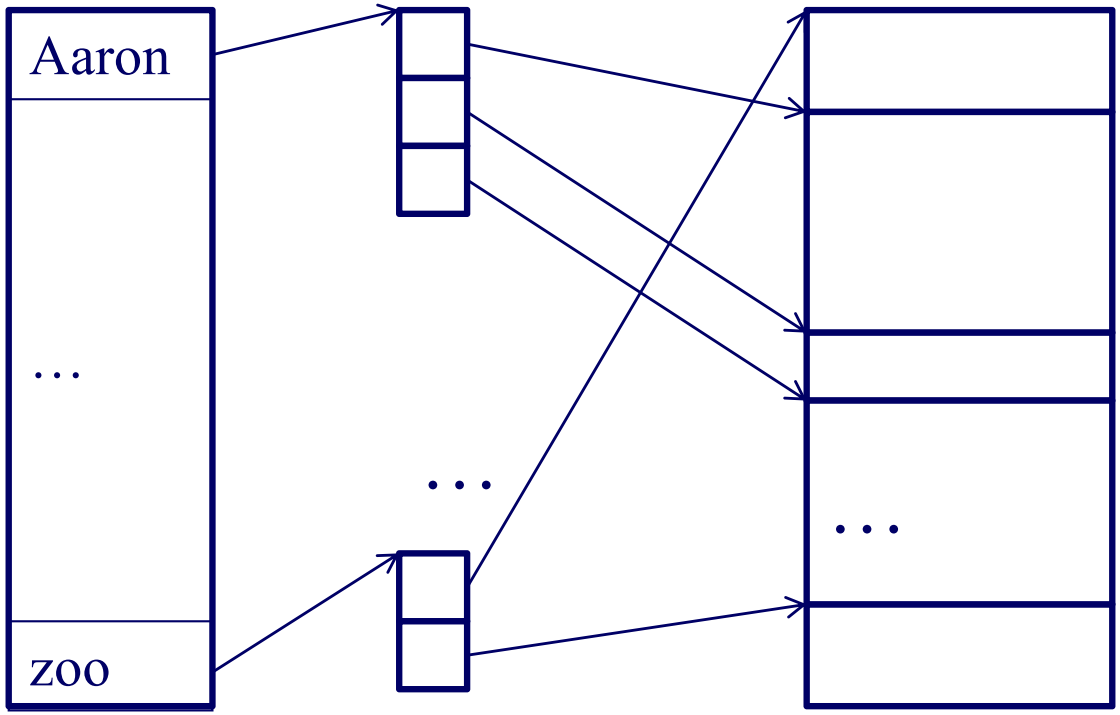
Text - Inversion



A: mainly, the postings lists

Text - Inversion

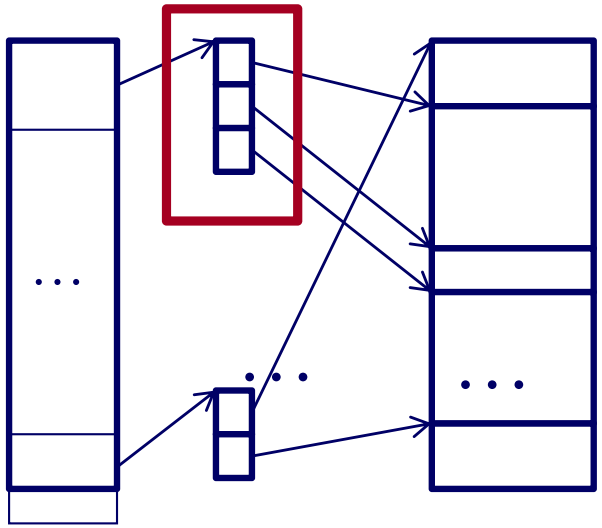
Dictionary Postings lists Text file



A: mainly, the postings lists **How to compress them?**

How to compress them?

- A1: record the differences [Zobel+]

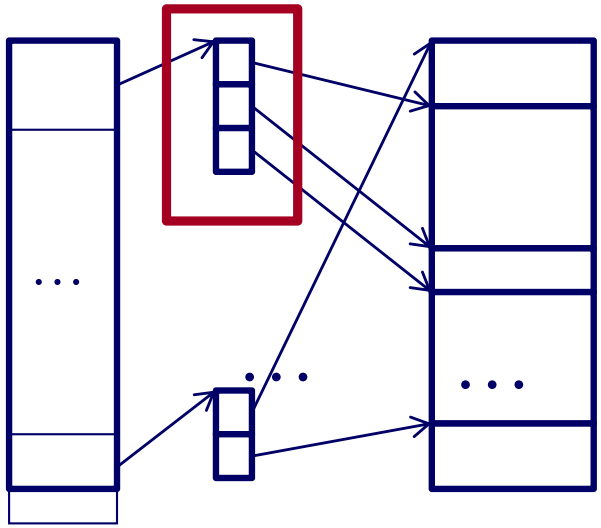


2,3,4 -> 3*4 bytes

Q: Something better?

How to compress them?

- A1: record the differences [Zobel+]

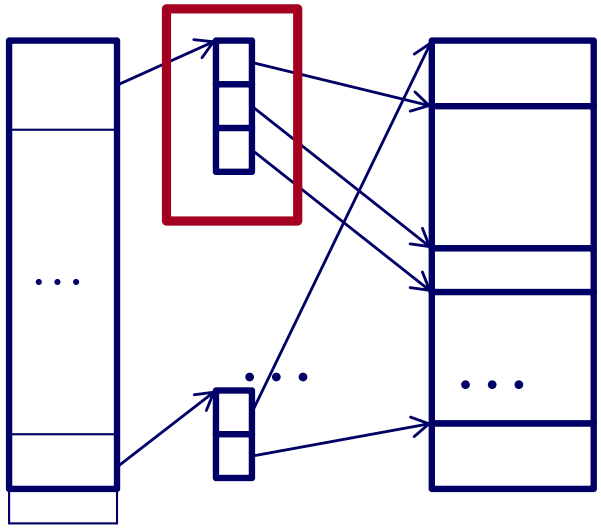


2,3,4 -> 3*4 bytes

Q: Something better?
A: encode *deltas*
Q': how?

How to compress them?

- A1: record the differences [Zobel+]



2,3,4 -> 3*4 bytes

Q: Something better?
A: encode *deltas*
Q': how?
A': Elias codes

‘short integers’ -> few bits’

- How exactly to achieve that
- So that they are self-delimiting?

Integer coding: small integers -> few bits

number	binary	Self-delimiting
2	10	00 1 10
3	11	00 1 11
15	1111	0000 1 1111

- *O (log (i))* bits for integer *i*
- can drop middle *'1'*
- can drop one of the zeros (!)
- (can apply recursively, to length)

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Integer coding: small integers -> few bits

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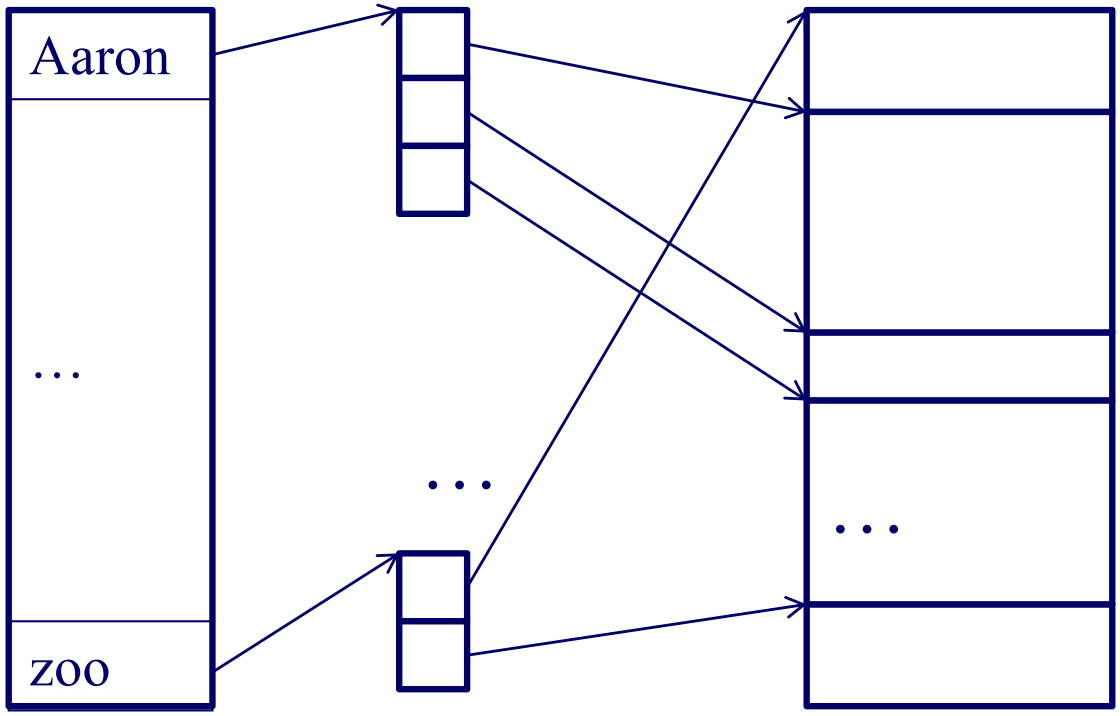
Integer coding: small integers -> few bits

number	binary	Self-delimiting
2	10	0 10
3	11	0 11
15	1111	000 1111

Elias gamma (γ) codes

Text - Inversion

Dictionary Postings lists Text file

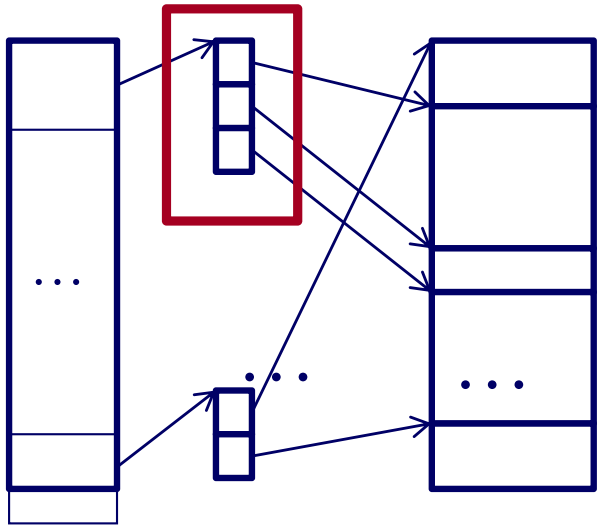


A: mainly, the postings lists

How to compress them EVEN MORE?

How to compress them?

- A1: record the differences [Zobel+]
- A2: REORDER/cluster the doc's



-> smaller deltas

Document Reordering

	Doc1	Doc2	Doc3			…
Aaron	**1**	0	**1**	0	**1**	0 …
…						
zoo	0	0	0	**1**	0	**1** …

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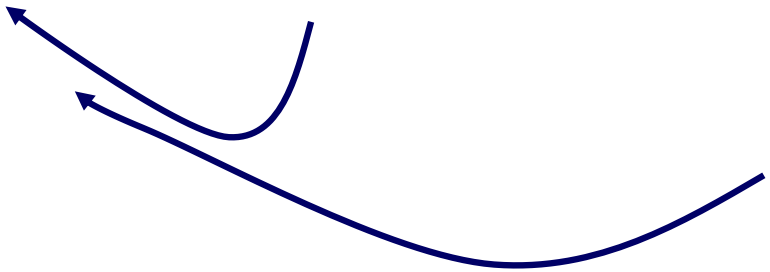
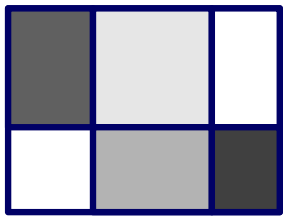
Document Reordering

	Doc1	Doc2	Doc3			
Aaron	**1**	0	**1**	0	**1**	0 …
…						
zoo	0	0	0	**1**	0	**1** …



Document Reordering

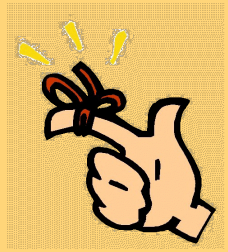
	Doc1	Doc3	…		Doc2
Aaron	**1**	**1**	**1**	0	0 0 …
…					
zoo	0	0	0	**1**	**1** 0 …



Shorter runs; easier to compress

Conclusions

- Conclusions: needs space overhead (2%-300%), but it is the fastest



Conclusion

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- ✔ A1: full text scanning
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- ✔ A2: inversion
  - Elias Codes
- (A3: signature files – 'Bloom filters')

Text - Detailed outline

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  - full text scanning
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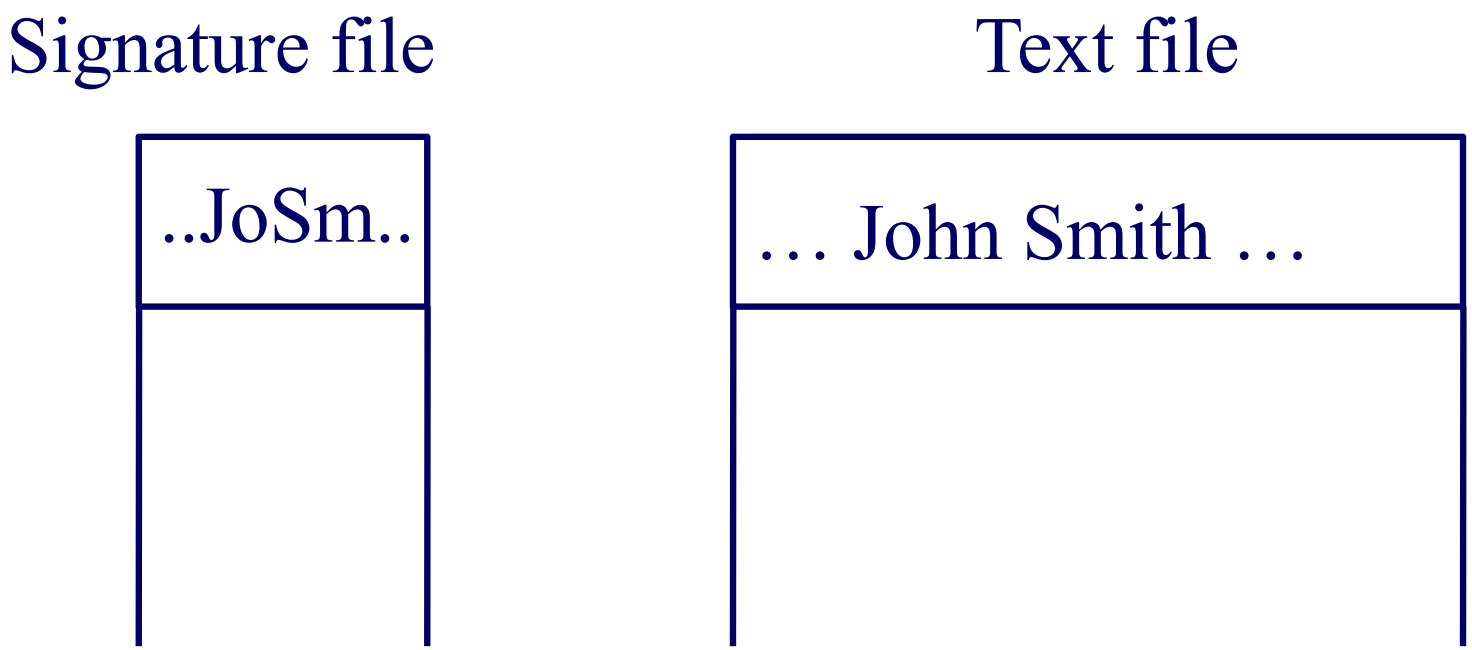
  - clustering
  - information filtering and LSI

Signature files

- idea: ‘quick & dirty’ filter



Signature files

- idea: ‘quick & dirty’ filter
- then, do seq. scan on sign. file and discard ‘false alarms’
- Adv.: easy insertions; faster than seq. scan
- Disadv.: O(N) search (with small constant)
- Q: how to extract signatures?

Signature files

- A: superimposed coding!! [Mooers49], ...

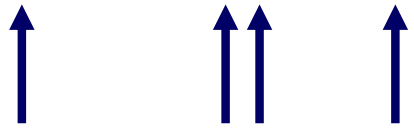
Word	Signature
data	001 000 110 010
base	000 010 101 001
doc.signature	001 010 111 011

m (=4 bits/word)
F (=12 bits sign. size)

Signature files

- A: superimposed coding!! [Mooers49], ...

Word	Signature
data	001 000 110 010
base	000 010 101 001
doc.signature	001 010 111 011

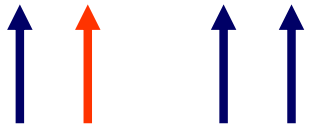
data 

actual match

Signature files

- A: superimposed coding!! [Mooers49], ...

Word	Signature
data	001 000 110 010
base	000 010 101 001
doc.signature	001 010 111 011

retrieval 

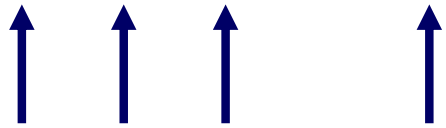
actual dismissal

Signature files

- A: superimposed coding!! [Mooers49], ...

Word	Signature
data	001 000 110 010
base	000 010 101 001
doc.signature	001 010 111 011

nucleotic



false alarm ('false drop')

Signature files

- A: superimposed coding!! [Mooers49], ...

Word	Signature
data	001 000 110 010
base	000 010 101 001
doc.signature	001 010 111 011

'YES' is 'MAYBE'
'NO' is 'NO'

Signature files

- Q1: How to choose *F* and *m* ?
- Q2: Why is it called ‘false drop’?
- Q3: other apps of signature files?

Signature files

- Q1: How to choose *F* and *m* ?

Word	Signature
data	001 000 110 010
base	000 010 101 001
doc.signature	001 010 111 011

m (=4 bits/word)
F (=12 bits sign. size)

Signature files

- Q1: How to choose F and m ?
- A: so that doc. signature is 50% full

Word	Signature
data	001 000 110 010
base	000 010 101 001
doc.signature	001 010 111 011

m (=4 bits/word)
F (=12 bits sign. size)

Signature files

- Q1: How to choose *F* and *m* ?
- Q2: Why is it called 'false drop'?
- Q3: other apps of signature files?

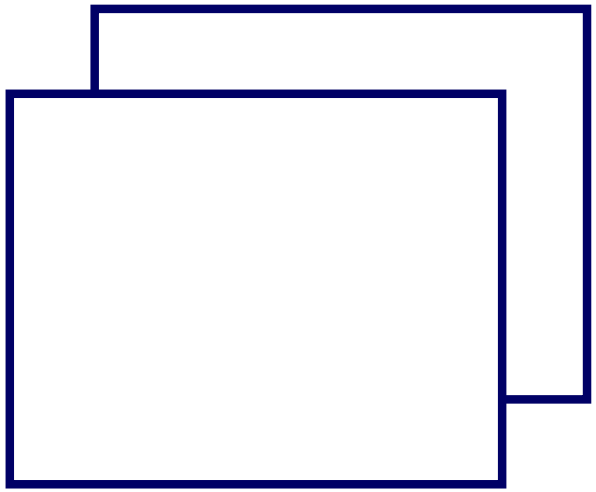
Signature files

- Q2: Why is it called ‘false drop’?
- Old, but fascinating story [Mooers, 1949]
  - how to find qualifying books (by title word, and/or author, and/or keyword)
  - in O(1) time?
  - **without computers** (1949…)

Calvin Mooers

Signature files

- 'State of the art': cards – but > O(1)



- one copy alpha by author
- one by title
- …

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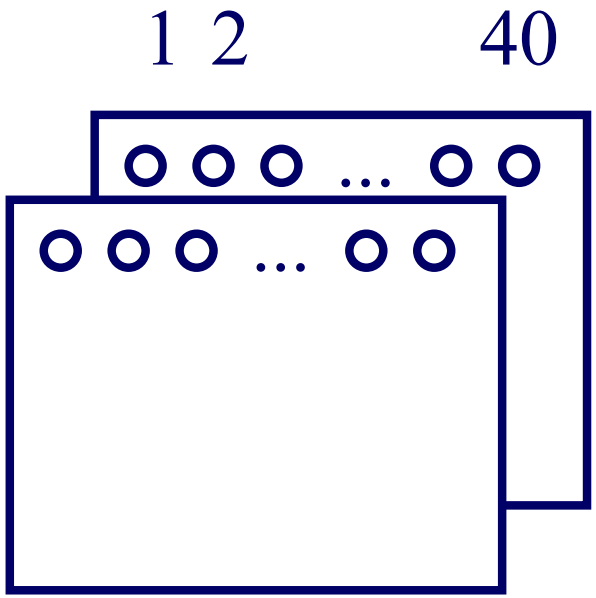
Signature files

- Solution: edge-notched cards



•each title word is mapped to *m* numbers (how?)
•and the corresponding holes are cut out:

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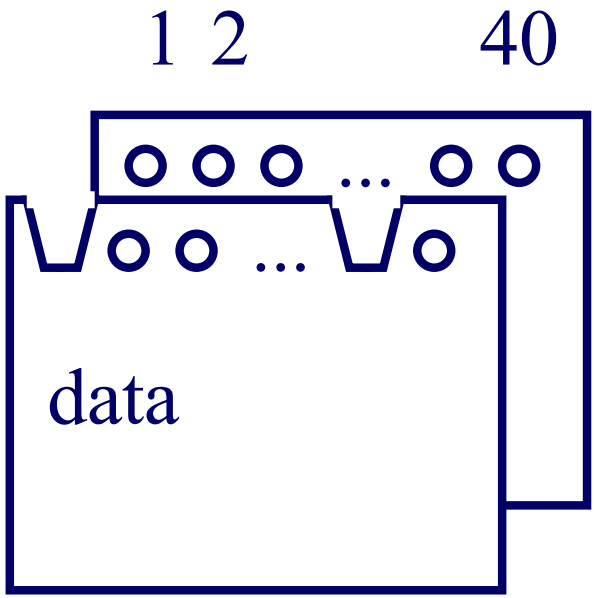
Signature files

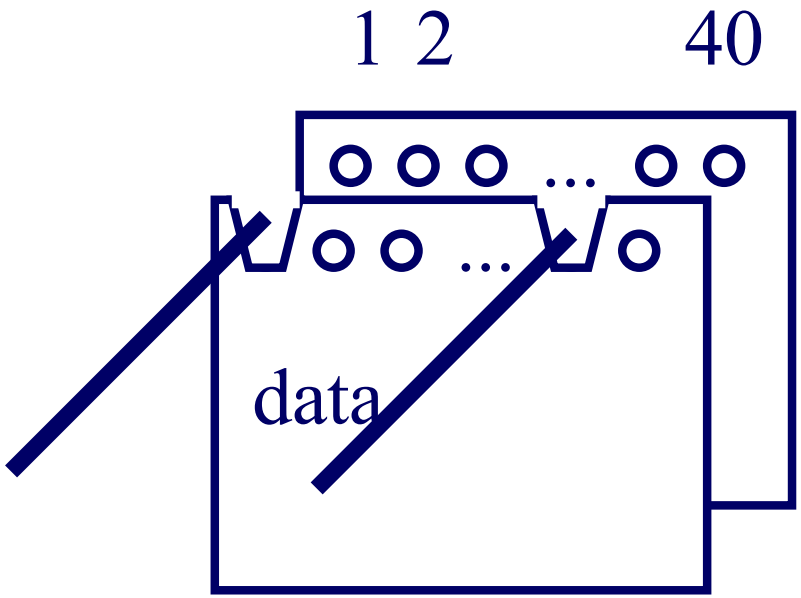
- Solution: edge-notched cards



'data' -> #1, #39

Signature files

- Search, e.g., for 'data': activate needle #1, #39, and shake the stack of cards!



'data' -> #1, #39

Signature files

- Also known as 'zatocoding', from 'Zator' company.

Signature files

- Q1: How to choose F and m ?
- Q2: Why is it called 'false drop'?
- Q3: other apps of signature files?

Signature files

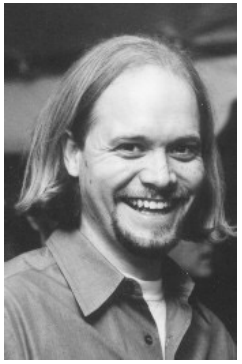
- Q3: other apps of signature files?
- A: anything that has to do with '**membership testing**': does '*data*' belong to the set of words of the document?

Word	Signature
data	001 000 110 010
base	000 010 101 001
doc.signature	001 010 111 011

Signature files

- UNIX's early 'spell' system [McIlroy]
- Bloom-joins in System R* [Mackert+] and 'active disks' [Riedel99]
- differential files [Severance + Lohman]
- Virus scan

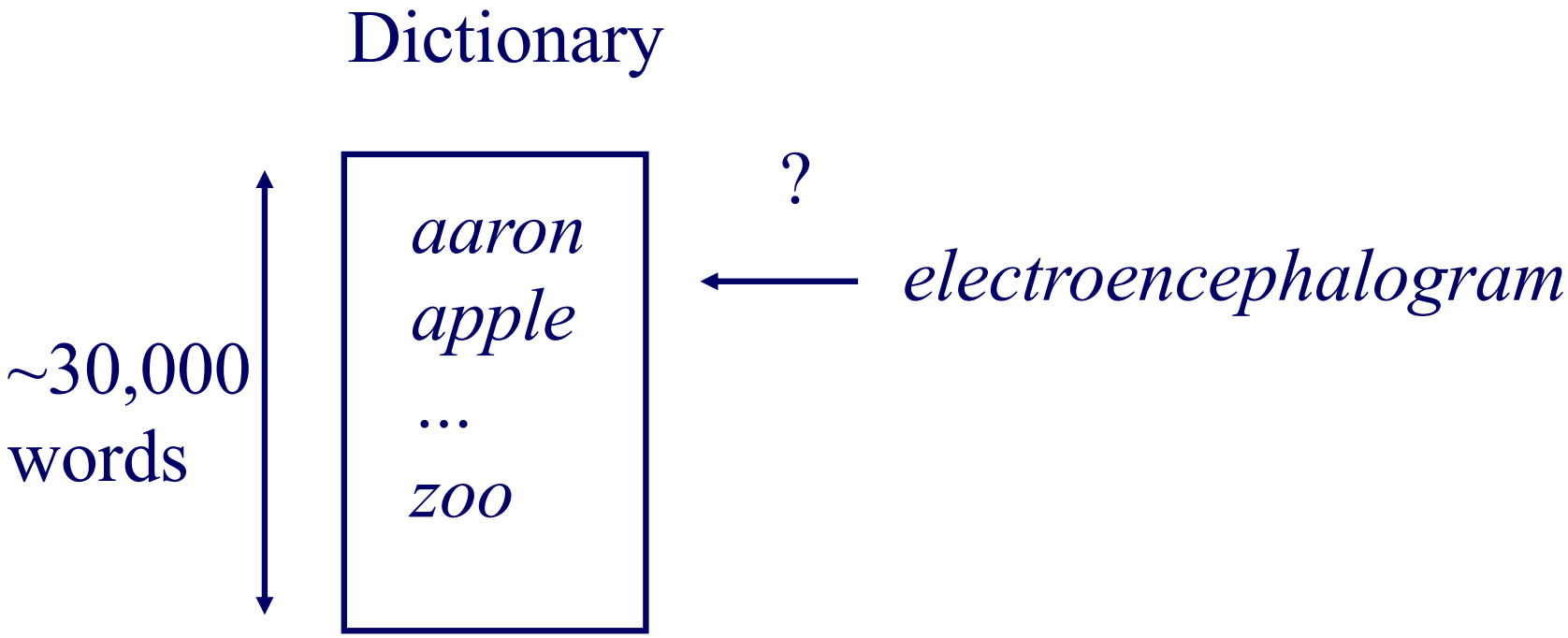
Doug McIlroy



Eric Riedel

Guy Lohman

App#1: Unix's spell



What to do if the dictionary does not fit in memory (~1980)?

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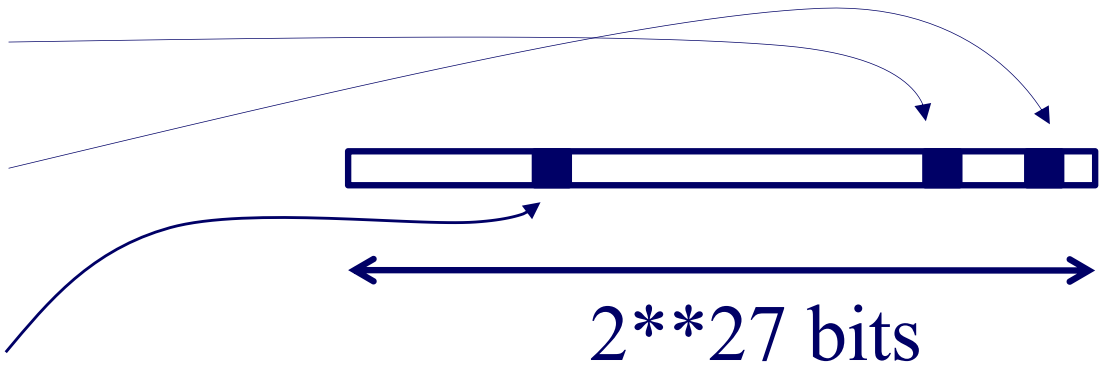
App#1: Unix's spell

A: allow for a few typos! And use

- huge bit string (2**27)
- Hash each dictionary word to a bit
- Compress the string

aaron
apple
...
zoo



App#1: Unix's spell

Sub-questions:

- Q1: How often do we allow typos?
- Q2: Will the (compressed) bit string fit in memory?
- Q3: How to compress the bit string?

App#2: Bloom-joins

R @Chicago

A	B	C
1		
1		
3		
…		
1		
12		

S @NY

A	E	F
1		
18		
1		
…		
23		
2		

R join S (@PIT)

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App#2: Bloom-joins

R @Chicago

A	B	C
1		
1		
3		
…		
1		
12		

S @NY

A	E	F
1		
18		
1		
…		
23		
2		

Idea: reduce transmission cost: 'R semijoin S'

App#2: Bloom-joins

Idea: reduce transmission cost: 'R semijoin S'

That is,
- 'S' ships its unique values of 'A'
- 'R' deletes non-matching tuples
- (and they both send their tuples to PIT)

Q: what if we want to send at most,
say 100 bytes NY -> Chicago?

App#2: Bloom-joins

Q: what if we want to send at most, say 100 bytes NY -> Chicago?

A: Bloom-join! Send a bloom filter of the S.A values

App#3: Differential files

Problem definition:

- A large file (eg., with EMPLOYEE records), nicely packed and organized (eg., B-tree)
- A few insertions/deletions, that we would like to keep separate, and merge, at night
- How to search, eg., for employee #123?

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App#3: Differential files

ssn	name	…
1		
5		
12		
…		
503		
509		

flag	ssn	name, ..
i	123	
i	55	
d	17	
d	33	

Differential file

App#3: Differential files

- Q: How to search, eg., for employee #123?
- A: bloom-filter, for keys of diff. file

- Q: What are the advantages of differential files?
- A: <see paper, for 10(!) of them>

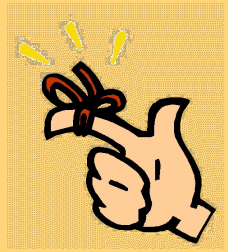
App#4: Virus-scan

- Q: How to search, for thousands of patterns?

- A: Bloom filter:
- *Exact Pattern Matching with Feed-Forward Bloom Filters,* J. Moraru, and D. Andersen, (ALENEX11) , Jan 2011

Signature files - conclusions

- easy insertions; slower than inversion
- brilliant idea of 'quick and dirty' filter: quickly discard the vast majority of non_qualifying elements, and focus on the rest.



Conclusion

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- ✔ A2: inversion
  - Elias Codes
- (A3: signature files – 'Bloom filters')

References

- Blandford, D. and Blelloch, G. 2002. *Index Compression through Document Reordering*. Data Compression Conference (DCC '02) (April 02 - 04, 2002).
- Brown, E. W., J. P. Callan, et al. (March 1994). *Supporting Full-Text Information Retrieval with a Persistent Object Store*. EDBT conference, Cambridge, U.K., Springer Verlag.

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- Karp, R. M. and M. O. Rabin (March 1987). "Efficient Randomized Pattern-Matching Algorithms." IBM Journal of Research and Development 31(2): 249-260.
- Knuth, D. E., J. H. Morris, et al. (June 1977). "Fast Pattern Matching in Strings." SIAM J. Comput 6(2): 323-350.

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- Manber, U. and S. Wu (1994). GLIMPSE: A Tool to Search Through Entire File Systems. Proc. of USENIX Techn. Conf.
- McIlroy, M. D. (Jan. 1982). "Development of a Spelling List." IEEE Trans. on Communications COM-30(1): 91-99.

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- Mooers, C. (1949). Application of Random Codes to the Gathering of Statistical Information Bulletin 31. Cambridge, Mass, Zator Co.
- Pedersen, D. C. a. J. (1990). Optimizations for dynamic inverted index maintenance. ACM SIGIR.
- Riedel, E. (1999). Active Disks: Remote Execution for Network Attached Storage. ECE, CMU. Pittsburgh, PA.

References - cont'd

- Severance, D. G. and G. M. Lohman (Sept. 1976). "Differential Files: Their Application to the Maintenance of Large Databases." ACM TODS 1(3): 256-267.
- Tomasic, A. and H. Garcia-Molina (1993). Performance of Inverted Indices in Distributed Text Document Retrieval Systems. PDIS.
- Tomasic, A., H. Garcia-Molina, et al. (May 24-27, 1994). Incremental Updates of Inverted Lists for Text Document Retrieval. ACM SIGMOD, Minneapolis, MN.

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- Wu, S. and U. Manber (1992). "AGREP- A Fast Approximate Pattern-Matching Tool." .
- Zobel, J., A. Moffat, et al. (Aug. 23-27, 1992). An Efficient Indexing Technique for Full-Text Database Systems. VLDB, Vancouver, B.C., Canada.