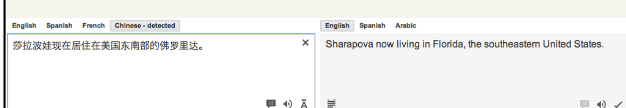
Index Construction

David Kauchak
cs458
Fall 2012
adapted from:
http://www.stanford.edu/class/cs276/handouts/lecture4-indexconstruction.ppt

Administrative

- Homework 1?
- Homework 2 out soon
- Issues with assignment 1?
- Talks Thursday
- videos?

Chinese



Google trends

Play with it at some point…

Many terms peak:
- Mitt Romney
- Michael Jackson

Some terms are cyclical:
- sunscreen
- christmas

Stemming

Reduce terms to their "roots" before indexing

The term "stemming" is used since it is accomplished mostly by chopping off part of the suffix of the word

automate ***automates*** ***automatic*** ***automation***	⇒	***automat***
run ***runs*** ***running***	⇒	***run***

Stemming example

Taking a course in information retrieval is more exciting than most courses

`Take a cours in inform retriev is more excit than most cours`

http://maya.cs.depaul.edu/~classes/ds575/porter.html
or use the class from assign1 to try some examples out

Porter's algorithm (1980)

Most common algorithm for stemming English

- Results suggest it's at least as good as other stemming options

Multiple sequential phases of reductions using rules, e.g.

- sses → ss
- ies → i
- ational → ate
- tional → tion

http://tartarus.org/~martin/PorterStemmer/

Lemmatization

Reduce inflectional/variant forms to base form

Stemming is an *approximation* for lemmatization

Lemmatization implies doing "proper" reduction to dictionary headword form

e.g.,

- *am, are, is → be*
- *car, cars, car's, cars' → car*

the boy's cars are different colors
the boy car be different color

What normalization techniques to use…

What is the size of the corpus?

- small corpora often require more normalization

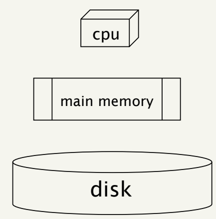
Depends on the users and the queries

Query suggestion (i.e. “did you mean”) can often be used instead of normalization

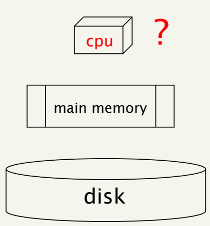
Most major search engines do little to normalize data except lowercasing and removing punctuation (and not even these always)

Hardware basics

Many design decisions in information retrieval are based on the characteristics of hardware



Hardware basics



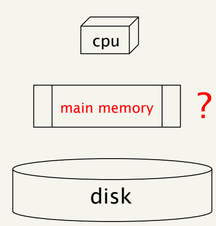
fast, particularly relative to hard-drive access times

gigahertz processors

multi-core

64-bit for larger workable address space

Hardware basics

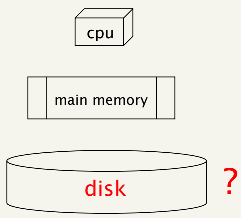


GBs to 100s of GBs for servers

main memory buses run at hundreds of megahertz

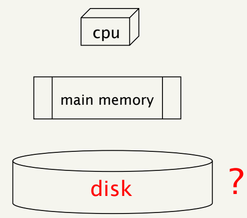
~random access

Hardware basics



- No data is transferred from disk while the disk head is being positioned
- Transferring one large chunk of data from disk to memory is faster than transferring many small chunks
- Disk I/O is block-based: Reading and writing of entire blocks (as opposed to smaller chunks).
- Block sizes: 8KB to 256 KB.

Hardware basics



- A few TBs
- average seek time 5 ms
- transfer time per byte 0.02 μs

RCV1: Our corpus for this lecture

- As an example for applying scalable index construction algorithms, we will use the Reuters RCV1 collection
- This is one year of Reuters newswire (part of 1995 and 1996)
- Still only a moderately sized data set

Extreme conditions create rare Antarctic clouds

Tue Aug 1, 2006 3:20am ET

Email This Article | Print This Article | Reprints

[-] Text [+]

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 RCV1 statistics

statistic	**value**
documents	800K
avg. # tokens per doc	200
terms	400K
non-positional postings	100M

Index construction

documents

1

2

…

m

index

word 1

word 2

…

word n

Input:
tokenized, normalized documents

Output:
postings lists sorted by docID

How can we do this?

Index construction: collecting docIDs

Doc 1

I did enact Julius Caesar I was killed i' the Capitol; Brutus killed me.

Doc 2

So let it be with Caesar. The noble Brutus hath told you Caesar was ambitious

Term	Doc #
I	1
did	1
enact	1
julius	1
caesar	1
I	1
was	1
killed	1
i'	1
the	1
capitol	1
brutus	1
killed	1
me	1
so	2
let	2
it	2
be	2
with	2
caesar	2
the	2
noble	2
brutus	2
hath	2
told	2
you	2
caesar	2
was	2
ambitious	2

running time?

Θ(tokens)

memory?

O(1)

now what?

Index construction: sort dictionary

Term	Doc #
I	1
did	1
enact	1
julius	1
caesar	1
I	1
was	1
killed	1
i'	1
the	1
capitol	1
brutus	1
killed	1
me	1
so	2
let	2
it	2
be	2
with	2
caesar	2
the	2
noble	2
brutus	2
hath	2
told	2
you	2
caesar	2
was	2
ambitious	2

sort based on terms

Term	Doc #
ambitious	2
be	2
brutus	1
brutus	2
capitol	1
caesar	1
caesar	2
caesar	2
did	1
enact	1
hath	1
I	1
I	1
i'	1
it	2
julius	1
killed	1
killed	1
let	2
me	1
noble	2
so	2
the	1
the	2
told	2
you	2
was	1
was	2
with	2

running time?

Θ(T log T)

memory?

Θ(T)

and then?

Index construction: create postings list

Term	Doc #
ambitious	2
be	2
brutus	1
brutus	2
capitol	1
caesar	1
caesar	2
caesar	2
did	1
enact	1
hath	1
I	1
I	1
i'	1
it	2
julius	1
killed	1
killed	1
let	2
me	1
noble	2
so	2
the	1
the	2
told	2
you	2
was	1
was	2
with	2

create postings lists from identical entries

word 1

word 2

…

word n

running time?

Θ(tokens)

What does this imply about the sorting algorithm?

Scaling index construction

In-memory index construction does not scale!

What is the major limiting step?

- both the collecting document IDs and creating posting lists require little memory since it's just a linear traversal of the data
- sorting is memory intensive! Even in-place sorting algorithms still require **O(n)** memory

Scaling index construction

In-memory index construction does not scale!

For RCV1:

statistic	value
documents	800K
avg. # tokens per doc	200
terms	400K
non-positional postings	100M

How much memory is required?

Scaling index construction

In-memory index construction does not scale!

For RCV1:

statistic	value
documents	800K
avg. # tokens per doc	200
terms	400K
non-positional postings	100M

What about for 10 years of news data?

Scaling index construction

In-memory index construction does not scale!

For RCV1:

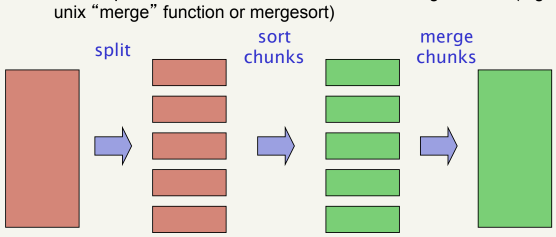
statistic	value
documents	800K
avg. # tokens per doc	200
terms	400K
non-positional postings	100M

What about for 300 billion web pages?

On-disk sorting

What are our options?

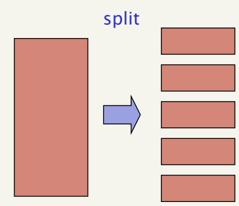
- sort on-disk: keep all data on disk. When we need to access entries, access entries
  - Random access on disk is slow……
- Break up list into chunks. Sort chunks, then merge chunks (e.g. unix “merge” function or mergesort)



On-disk sorting: splitting

Do this while processing

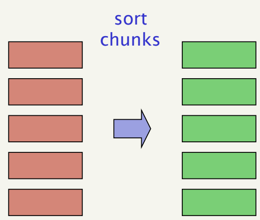
When we reach a particular size, start the sorting process



On-disk sorting: sorting chunks

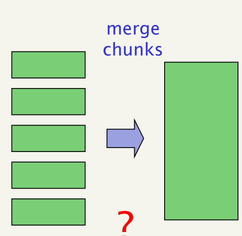
Pick the chunk size so that we can sort the chunk in memory

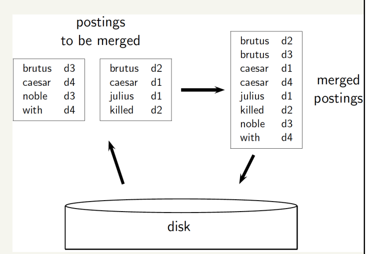
Generally, pick as large a chunk as possible while still being able to sort in memory



On-disk sorting

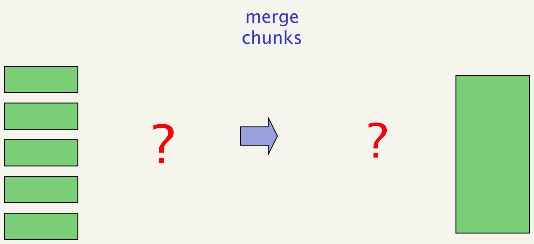
How can we do this?





On-disk sorting

How can we do this so that it is time and memory efficient?

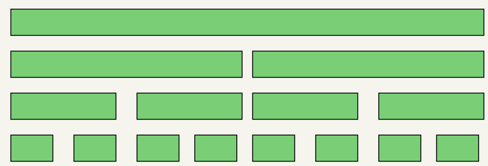


Binary merges

Could do binary merges, with a merge tree

For *n* chunks, how many levels will there be?

- log(n)



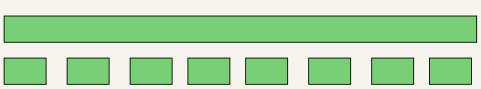
n-way merge

More efficient to do an *n*-way merge, where you are reading from all blocks simultaneously

Providing you read decent-sized chunks of each block into memory, you're not killed by disk seeks

Only one level of merges!

Is it linear?



Another approach: SPIMI

Sorting can still be expensive

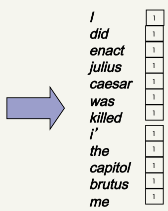
Is there any way to do the indexing without sorting?

- Accumulate posting lists as they occur
- When size gets too big, start a new chunk
- Merge chunks at the end

Another approach

Doc 1

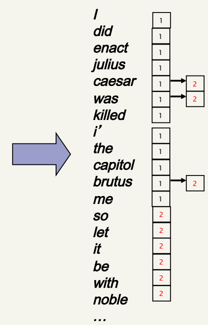
I did enact Julius Caesar I was killed i' the Capitol; Brutus killed me.



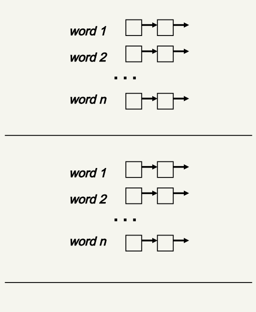
Another approach

Doc 2

So let it be with Caesar. The noble Brutus hath told you Caesar was ambitious

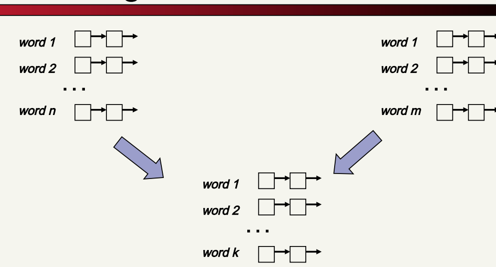


Another approach



When posting lists get to large to fit in memory, we write to disk and start another one

The merge



Running time?

- linear in the sizes of the postings list being merged

As with merging sorted dictionary entries we can either do pairwise binary tree type merging or do an *n*-way merge

Distributed indexing

For web-scale indexing **we must** use a distributed computing cluster

Individual machines are fault-prone

- Can unpredictably slow down or fail

How do we exploit such a pool of machines?

Google data centers

Google data centers mainly contain commodity machines

Data centers are distributed around the world

Estimates:

- 2011: a total of 1 million servers, 3 million processors
- Google says: In planning 1 million – 10 million machines
- Google installs 100,000 servers each quarter
  - Based on expenditures of 200–250 million dollars per year
  - This would be 10% of the computing capacity of the world!?!
- 0.01% of the total worldwide electricity

Fault tolerance

Hardware failures

>30% chance of failure within 5 years

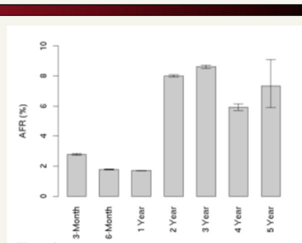


Figure 2: Annualized failure rates broken down by age groups

http://labs.google.com/papers/disk_failures.pdf

What happens when you have 1 million servers?

Hardware is always failing!