Web Crawling and Basic Text Analysis

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Recap: core IR concepts

- Information need
  - An IR system is to satisfy users' information need
- Query
  - A designed representation of users' information need
- Document
  - A representation of information that potentially satisfies users' information need
- Relevance
  - Relatedness between documents and users' information need

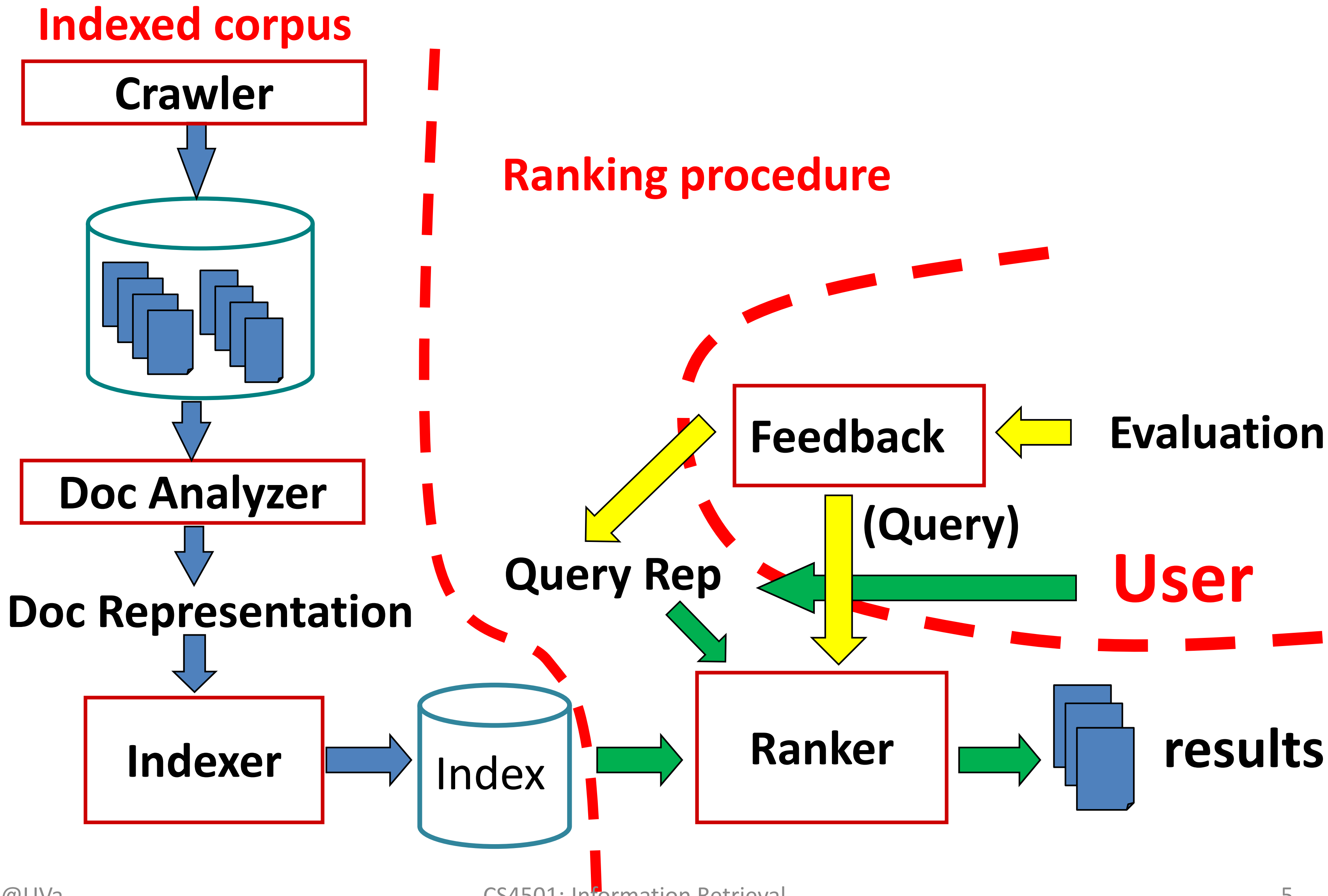
Recap: Browsing v.s. Querying

- Browsing
  - Works well when the user wants to explore information or doesn’t know what keywords to use, or can’t conveniently enter a query
- Querying
  - Works well when the user knows exactly what query to use for expressing her information need

Recap: Pull v.s. Push in IR

- Pull mode – with query
  - User takes the initiative
  - Works well when a user has an ad hoc information need
- Push mode – without query
  - System takes the initiative
  - Works well when a user has a stable information need or the system has good knowledge about a user’s need

Abstraction of search engine architecture



Web crawler

- A automatic program that systematically browses the web for the purpose of Web content indexing and updating
  - Synonyms: spider, robot, bot

How does it work

- In pseudo code

```
Def Crawler(entry_point) {
    URL_list = [entry_point]
    while (len(URL_list)>0) {
        URL = URL_list.pop();
        if (isVisited(URL) or !isLegal(URL) or !checkRobotsTxt(URL))
            continue;
        HTML = URL.open();
        for (anchor in HTML.listOfAnchors()) {
            URL_list .append(anchor);
        }
        setVisited(URL);
        insertToIndex(HTML);
    }
}
```

Which page to visit next?

Is it visited already?
Or shall we visit it again?

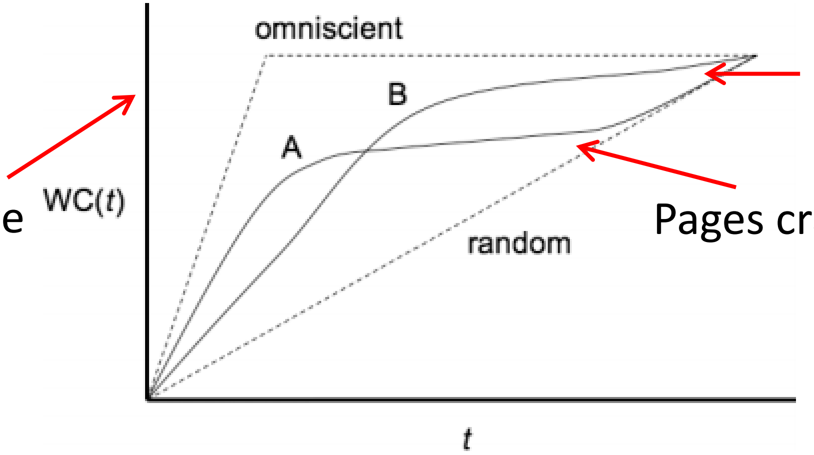
Is the access granted?

Visiting strategy

- Breadth first
  - Uniformly explore from the entry page
  - Memorize all nodes on the previous level
  - As shown in pseudo code
- Depth first
  - Explore the web by branch
  - Biased crawling given the web is not a tree structure
- Focused crawling
  - Prioritize the new links by predefined strategies

Focused crawling

- Prioritize the visiting sequence of the web
  - The size of Web is too large for a crawler (even Google) to completely cover
    - In 1999, no search engine indexed more than 16% of the Web
    - In 2005, large-scale search engines index no more than 40-70% of the indexable Web
  - Not all documents are equally important
  - Emphasize more on the high-quality documents
    - Maximize weighted coverage



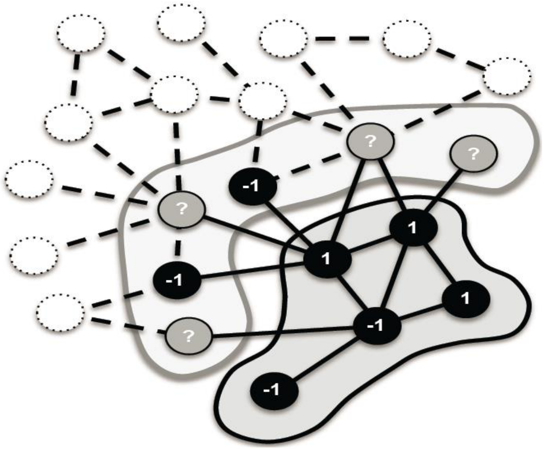
Weighted coverage till time ***t***

Importance of page ***p***

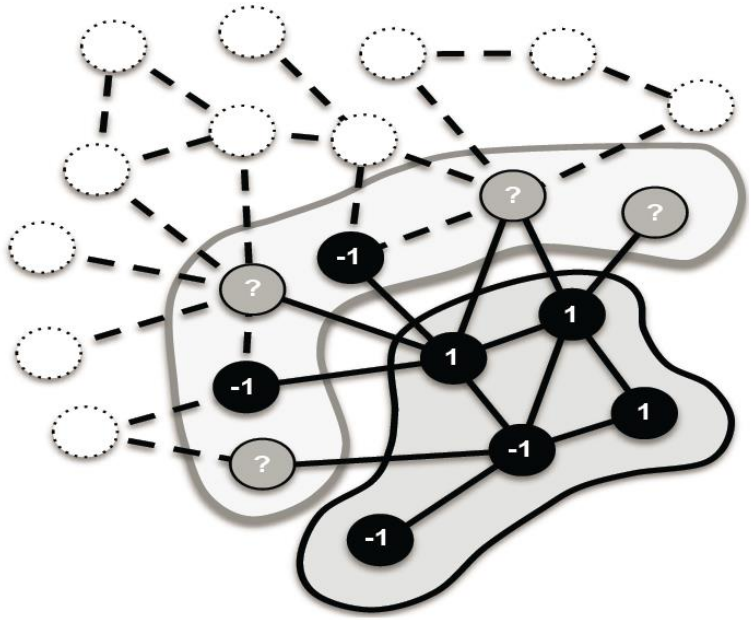
Pages crawled till time ***t***

Focused crawling

- Prioritize by in-degree [Cho et al. WV
  - The page with the highest numbe hyperlinks from previously downl downloaded next



- Prioritize by l. WWW'07, Cho and Uri VLDB'07]
  - Breadth-fi compute/ eriodically
  - More con nce [Fetterly et al. SIGIR'09]



Focused crawling

- Prioritize by topical relevance
  - In vertical search, only crawl relevant pages [De et al. WWW'94]
    - E.g., restaurant search engine should only crawl restaurant pages
  - Estimate the similarity to current page by anchortext or text near anchor [Hersovici et al. WWW'98]
  - User given taxonomy or topical classifier [Chakrabarti et al. WWW'98]

Avoid duplicate visit

- Given web is a graph rather than a tree, avoid loop in crawling is important
- What to check
  - URL: must be normalized, not necessarily can avoid all duplication
    - http://dl.acm.org/event.cfm?id=RE160&CFID=516168213&CFTOKEN=99036335
    - http://dl.acm.org/event.cfm?id=RE160
  - Page: minor change might cause misfire
    - Timestamp, data center ID change in HTML
- How to check
  - trie or hash table

Politeness policy

- Crawlers can retrieve data much quicker and in greater depth than human searchers
- Costs of using Web crawlers
  - Network resources
  - Server overload
- Robots exclusion protocol
  - Examples: CNN, UVa

Robot exclusion protocol examples

- Exclude specific directories:

```
User-agent: *
 Disallow: /tmp/
 Disallow: /cgi-bin/
 Disallow: /users/paranoid/
```

- Exclude a specific robot:

```
User-agent: GoogleBot
 Disallow: /
```

- Allow a specific robot:

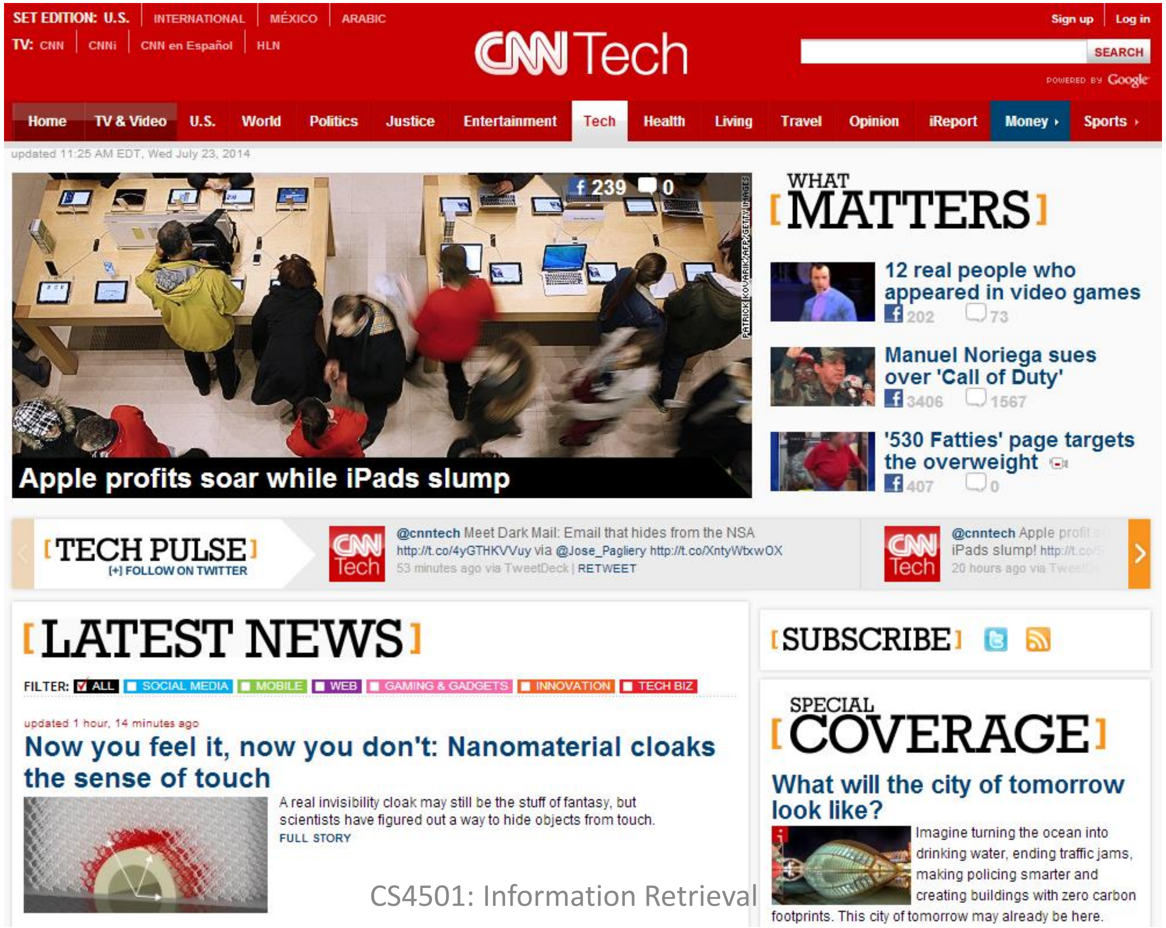
```
User-agent: GoogleBot
 Disallow:

 User-agent: *
 Disallow: /
```

Re-visit policy

- The Web is very dynamic; by the time a Web crawler has finished its crawling, many events could have happened, including creations, updates and deletions
  - Keep re-visiting the crawled pages
  - Maximize freshness and minimize age of documents in the collection
- Strategy
  - Uniform re-visiting
  - Proportional re-visiting
    - Visiting frequency is proportional to the page's update frequency

Analyze crawled web pages

- What you care from the crawled web pages



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Apple profits soar while iPads slump

WHAT [MATTERS]

12 real people who appeared in video games
f 202 73

Manuel Noriega sues over 'Call of Duty'
f 3406 1567

'530 Fatties' page targets the overweight
f 407 0

[TECH PULSE]
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@cnntech Apple profit
iPads slump! http://t.co/
20 hours ago via Twe

[LATEST NEWS]

FILTER: ☑ ALL □ SOCIAL MEDIA □ MOBILE □ WEB □ GAMING & GADGETS □ INNOVATION □ TECH BIZ

updated 1 hour, 14 minutes ago

Now you feel it, now you don't: Nanomaterial cloaks the sense of touch

A real invisibility cloak may still be the stuff of fantasy, but scientists have figured out a way to hide objects from touch.
FULL STORY

[SUBSCRIBE]

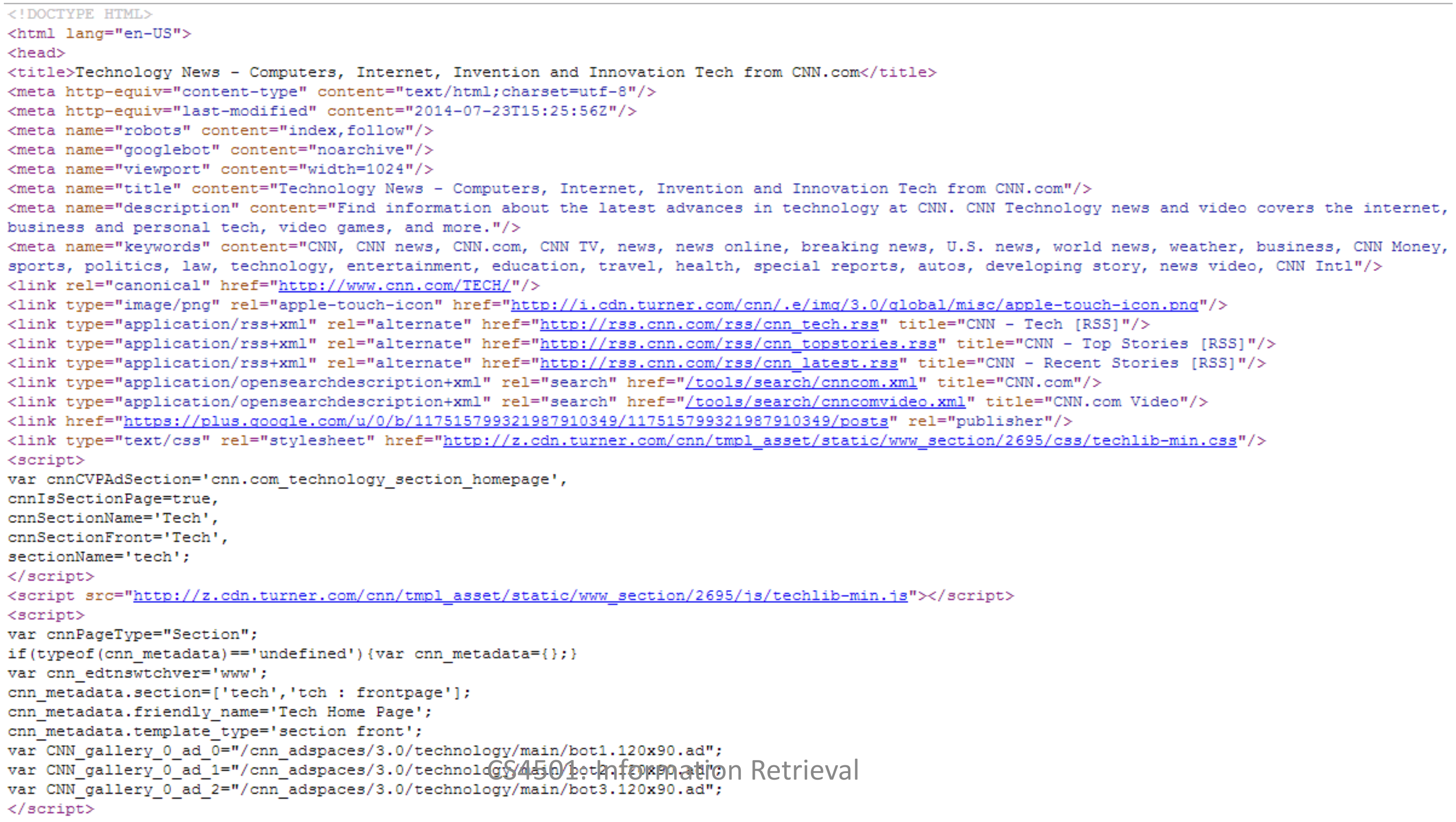
SPECIAL [COVERAGE]

What will the city of tomorrow look like?

Imagine turning the ocean into drinking water, ending traffic jams, making policing smarter and creating buildings with zero carbon footprints. This city of tomorrow may already be here.

Analyze crawled web pages

- What machine knows from the crawled web pages



```
<!DOCTYPE HTML>
<html lang="en-US">
<head>
<title>Technology News - Computers, Internet, Invention and Innovation Tech from CNN.com</title>
<meta http-equiv="content-type" content="text/html;charset=utf-8"/>
<meta http-equiv="last-modified" content="2014-07-23T15:25:56Z"/>
<meta name="robots" content="index,follow"/>
<meta name="googlebot" content="noarchive"/>
<meta name="viewport" content="width=1024"/>
<meta name="title" content="Technology News - Computers, Internet, Invention and Innovation Tech from CNN.com"/>
<meta name="description" content="Find information about the latest advances in technology at CNN. CNN Technology news and video covers the internet,
business and personal tech, video games, and more."/>
<meta name="keywords" content="CNN, CNN news, CNN.com, CNN TV, news, news online, breaking news, U.S. news, world news, weather, business, CNN Money,
sports, politics, law, technology, entertainment, education, travel, health, special reports, autos, developing story, news video, CNN Intl"/>
<link rel="canonical" href="http://www.cnn.com/TECH/"/>
<link type="image/png" rel="apple-touch-icon" href="http://i.cdn.turner.com/cnn/.e/img/3.0/global/misc/apple-touch-icon.png"/>
<link type="application/rss+xml" rel="alternate" href="http://rss.cnn.com/rss/cnn_tech.rss" title="CNN - Tech [RSS]"/>
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<link type="application/rss+xml" rel="alternate" href="http://rss.cnn.com/rss/cnn_latest.rss" title="CNN - Recent Stories [RSS]"/>
<link type="application/opensearchdescription+xml" rel="search" href="/tools/search/cnncom.xml" title="CNN.com"/>
<link type="application/opensearchdescription+xml" rel="search" href="/tools/search/cnncomvideo.xml" title="CNN.com Video"/>
<link href="https://plus.google.com/u/0/b/117515799321987910349/117515799321987910349/posts" rel="publisher"/>
<link type="text/css" rel="stylesheet" href="http://z.cdn.turner.com/cnn/tmpl_asset/static/www_section/2695/css/techlib-min.css"/>
<script>
var cnnCVPAdSection='cnn.com_technology_section_homepage',
cnnIsSectionPage=true,
cnnSectionName='Tech',
cnnSectionFront='Tech',
sectionName='tech';
</script>
<script src="http://z.cdn.turner.com/cnn/tmpl_asset/static/www_section/2695/js/techlib-min.js"></script>
<script>
var cnnPageType="Section";
if(typeof(cnn_metadata)=='undefined'){var cnn_metadata={};}
var cnn_edtnswtchver='www';
cnn_metadata.section=['tech','tch : frontpage'];
cnn_metadata.friendly_name='Tech Home Page';
cnn_metadata.template_type='section front';
var CNN_gallery_0_ad_0="/cnn_adspaces/3.0/technology/main/bot1.120x90.ad";
var CNN_gallery_0_ad_1="/cnn_adspaces/3.0/technology/main/bot2.120x90.ad";
var CNN_gallery_0_ad_2="/cnn_adspaces/3.0/technology/main/bot3.120x90.ad";
</script>
```

Basic text analysis techniques

- Needs to analyze and index the crawled web pages
  - Extract informative content from HTML
  - Build machine accessible data representation

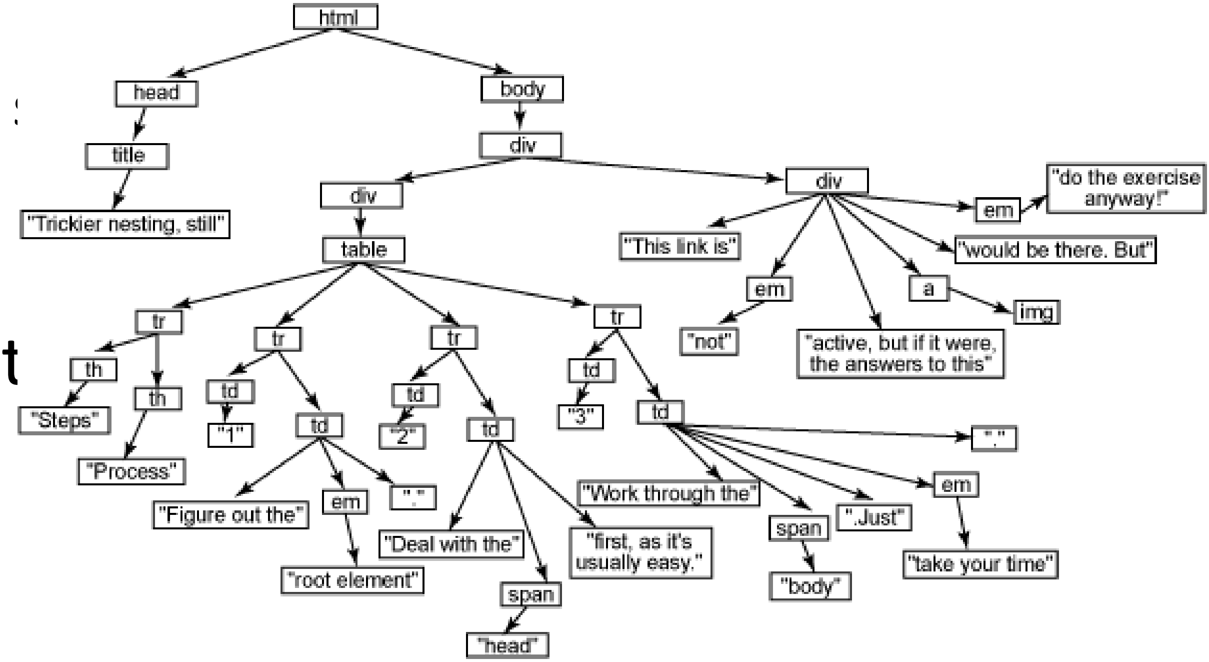
HTML parsing

- Generally difficult due to the free style of HTML
- Solutions
  - Shallow parsing
    - Remove all HTML tags
    - Only keep text between <title></title> and <p></p>
  - Automatic wrapper generation [Crescenzi et al. VLDB'01]
    - Wrapper: regular expression for HTML tags' combination
    - Inductive reasoning from examples
  - Visual parsing [Yang and Zhang DAR'01]
    - Frequent pattern mining of visually similar HTML blocks

HTML parsing

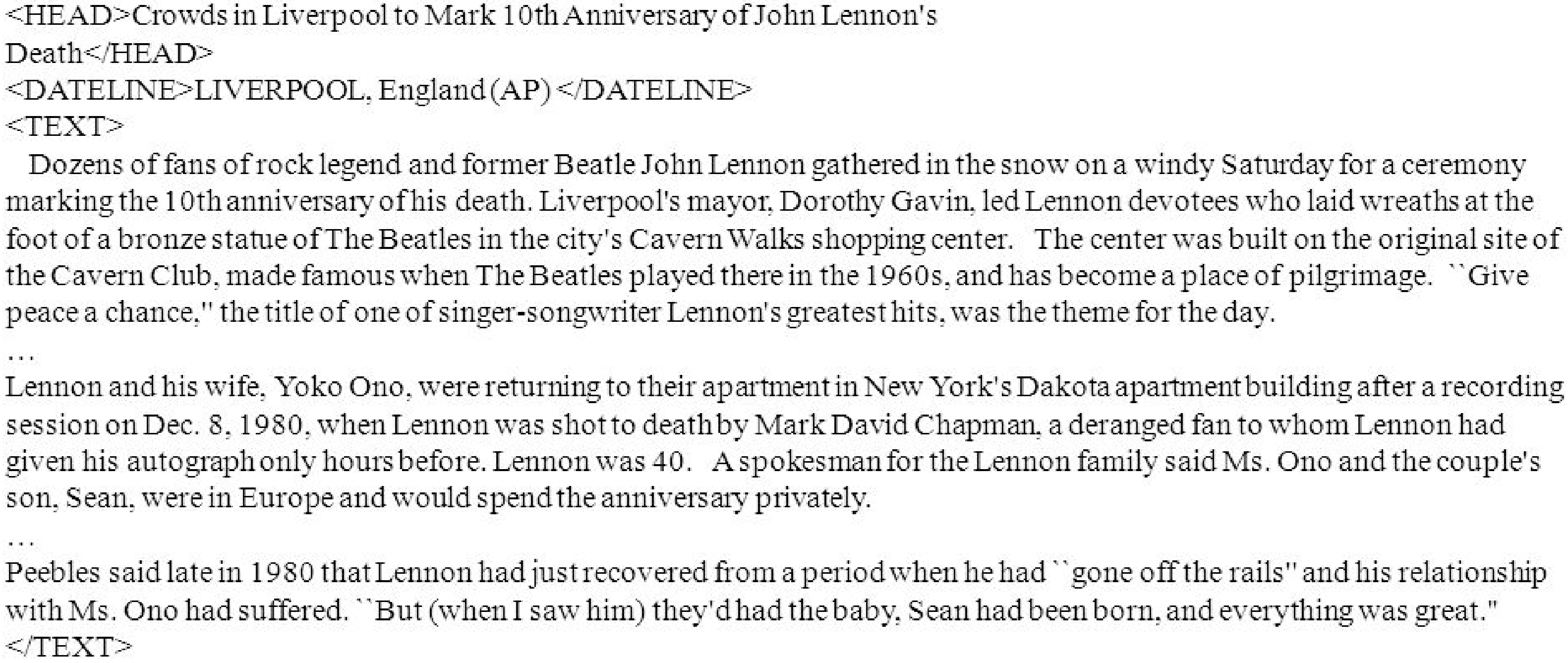
- jsoup
  - Java-based HTML parser
    - scrape and parse HTML from a URL, file, or string to DOM tree
    - CSS

      e()
  - Pyt



How to represent a document

- Represent by a string?



<HEAD>Crowds in Liverpool to Mark 10th Anniversary of John Lennon's Death</HEAD>
<DATELINE>LIVERPOOL, England (AP) </DATELINE>
<TEXT>
Dozens of fans of rock legend and former Beatle John Lennon gathered in the snow on a windy Saturday for a ceremony marking the 10th anniversary of his death. Liverpool's mayor, Dorothy Gavin, led Lennon devotees who laid wreaths at the foot of a bronze statue of The Beatles in the city's Cavern Walks shopping center. The center was built on the original site of the Cavern Club, made famous when The Beatles played there in the 1960s, and has become a place of pilgrimage. ``Give peace a chance,'' the title of one of singer-songwriter Lennon's greatest hits, was the theme for the day.
…
Lennon and his wife, Yoko Ono, were returning to their apartment in New York's Dakota apartment building after a recording session on Dec. 8, 1980, when Lennon was shot to death by Mark David Chapman, a deranged fan to whom Lennon had given his autograph only hours before. Lennon was 40. A spokesman for the Lennon family said Ms. Ono and the couple's son, Sean, were in Europe and would spend the anniversary privately.
…
Peebles said late in 1980 that Lennon had just recovered from a period when he had ``gone off the rails'' and his relationship with Ms. Ono had suffered. ``But (when I saw him) they'd had the baby, Sean had been born, and everything was great.''
</TEXT>

  - Bag-of-Words representation!

Tokenization

- Break a stream of text into meaningful units
  - Tokens: words, phrases, symbols
    - **Input:** It’s not straight-forward to perform so-called “tokenization.”
    - **Output(1):** 'It’s', 'not', 'straight-forward', 'to', 'perform', 'so-called', '“tokenization.”'
    - **Output(2):** 'It', '’', 's', 'not', 'straight', '-', 'forward, 'to', 'perform', 'so', '-', 'called', ‘“', 'tokenization', '.', '”‘
  - Definition depends on language, corpus, or even context

Tokenization

- Solutions
  - Regular expression
    - [\w]+: so-called -> ‘so’, ‘called’
    - [\S]+: It’s -> ‘It’s’ instead of ‘It’, ‘’s’
  - Statistical methods
    - Explore rich features to decide where is the boundary of a word
      - Apache OpenNLP (http://opennlp.apache.org/)
      - Stanford NLP Parser (http://nlp.stanford.edu/software/lex-parser.shtml)
    - Online Demo
      - Stanford (http://nlp.stanford.edu:8080/parser/index.jsp)
      - UIUC (http://cogcomp.cs.illinois.edu/curator/demo/index.html)

Full text indexing

- Bag-of-Words representation
  - Doc1: Information retrieval is helpful for everyone.
  - Doc2: Helpful information is retrieved for you.

	information	retrieval	retrieved	is	helpful	for	you	everyone
Doc1	1	1	0	1	1	1	0	1
Doc2	1	0	1	1	1	1	1	0

Word-document adjacency matrix

Full text indexing

- Bag-of-Words representation
  - Assumption: word is independent from each other
  - Pros: simple
  - Cons: grammar and order are missing
  - ***The most frequently used document representation***
    - ***Image, speech, gene sequence***

Full text indexing

- Improved Bag-of-Words representation
  - N-grams: a contiguous sequence of n items from a given sequence of text
    - E.g., Information retrieval is helpful for everyone
    - Bigrams: ‘information_retrieval’, ‘retrieval_is’, ‘is_helpful’, ‘helpful_for’, ‘for_everyone’
  - Pros: capture local dependency and order
  - Cons: purely statistical view, increase vocabulary size $O(V^N)$

Full text indexing

- Index document with all the occurring word
  - Pros
    - Preserve all information in the text (hopefully)
    - Fully automatic
  - Cons
    - Vocabulary gap: cars v.s., car
    - Large storage: e.g., in N-grams $O(V^N)$
  - Solution
    - Construct controlled vocabulary

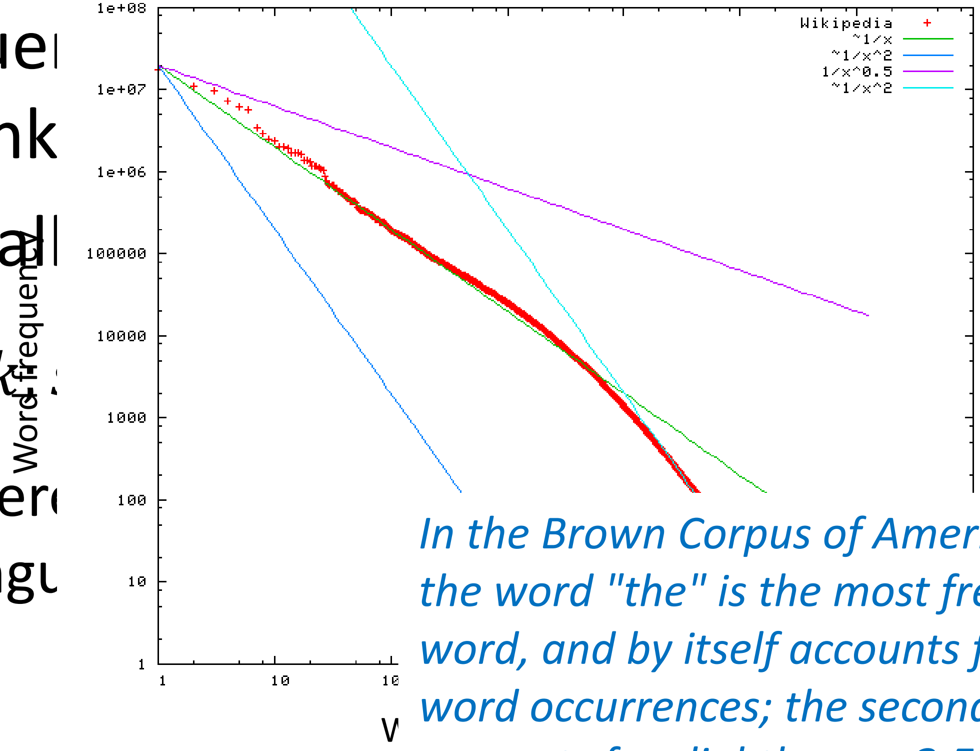
Statistical property of language

- Zipf’s law

discrete version of power law

  - Freque portional to its rank
  - Formall
    - $f(k;$

      wher bulary size; s is langu



A plot of word frequ

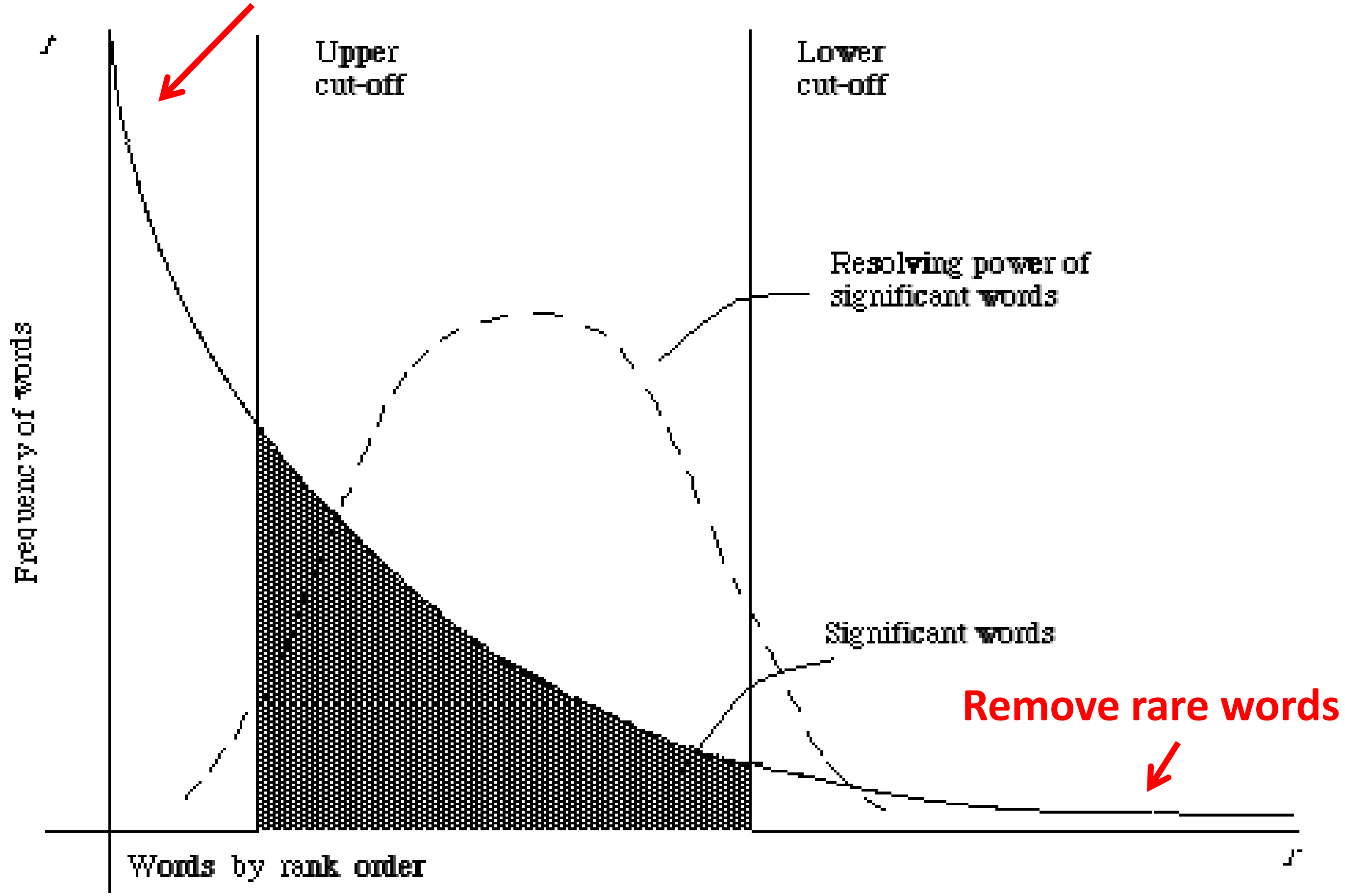
In the Brown Corpus of American English text, the word "the" is the most frequently occurring word, and by itself accounts for nearly ***7%*** *of all word occurrences; the second-place word "of" accounts for slightly over* ***3.5%*** *of words.*

Zipf's law tells us

- Head words may take large portion of occurrence, but they are semantically meaningless
  - E.g., the, a, an, we, do, to
- Tail words take major portion of vocabulary, but they rarely occur in documents
  - E.g., dextrosinistral
- The rest is most representative
  - To be included in the controlled vocabulary

Automatic text indexing

Remove non-informative words



Remove rare words

Figure 2.1. A plot of the hyperbolic curve relating f, the frequency of occurrence and r, the rank order (Adaped from Schultz[44] page 120)

Normalization

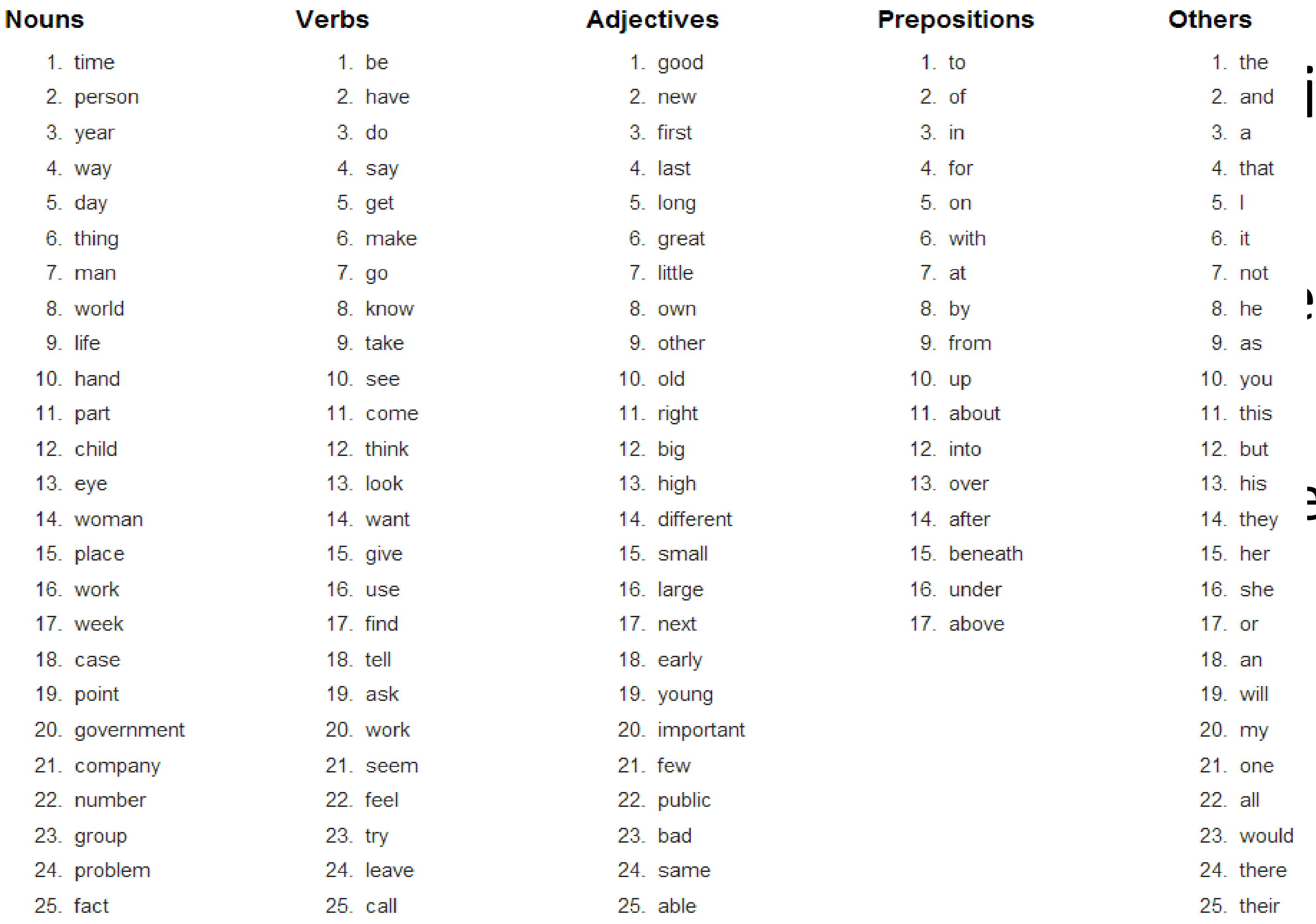
- Convert different forms of a word to normalized form in the vocabulary
  - U.S.A -> USA, St. Louis -> Saint Louis
- Solution
  - Rule-based
    - Delete periods and hyphens
    - All in lower case
  - Dictionary-based
    - Construct equivalent class
      - Car -> “automobile, vehicle”
      - Mobile phone -> “cellphone”

Stemming

- Reduce inflected or derived words to their root form
  - Plurals, adverbs, inflected word forms
    - E.g., ladies -> lady, referring -> refer, forgotten -> forget
  - Bridge the vocabulary gap
  - Risk: lose precise meaning of the word
    - E.g., lay -> lie (a false statement? or be in a horizontal position?)
  - Solutions (for English)
    - Porter stemmer: pattern of vowel-consonant sequence
    - Krovetz Stemmer: morphological rules

Stopwords

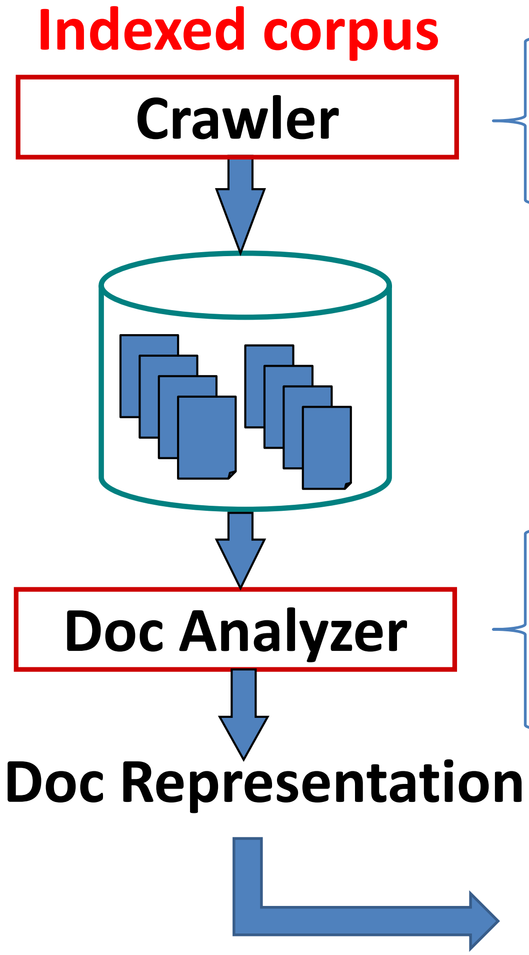
- U is
  -
  - e
  -
  - e of



	Nouns	Verbs	Adjectives	Prepositions	Others
1.	time	be	good	to	the
2.	person	have	new	of	and
3.	year	do	first	in	a
4.	way	say	last	for	that
5.	day	get	long	on	I
6.	thing	make	great	with	it
7.	man	go	little	at	not
8.	world	know	own	by	he
9.	life	take	other	from	as
10.	hand	see	old	up	you
11.	part	come	right	about	this
12.	child	think	big	into	but
13.	eye	look	high	over	his
14.	woman	want	different	after	they
15.	place	give	small	beneath	her
16.	work	use	large	under	she
17.	week	find	next	above	or
18.	case	tell	early		an
19.	point	ask	young		will
20.	government	work	important		my
21.	company	seem	few		one
22.	number	feel	public		all
23.	group	try	bad		would
24.	problem	leave	same		there
25.	fact	call	able		their

The OEC: Facts about the language

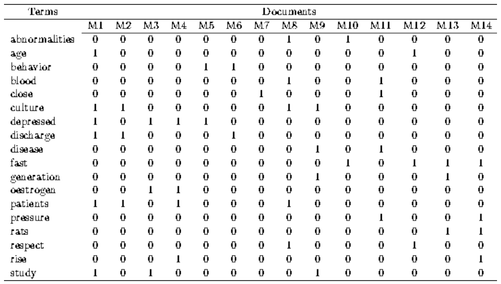
Abstraction of search engine architecture



Indexed corpus

1. Visiting strategy
2. Avoid duplicated visit
3. Re-visit policy

1. HTML parsing
2. Tokenization
3. Stemming/normalization
4. Stopword/controlled vocabulary filter



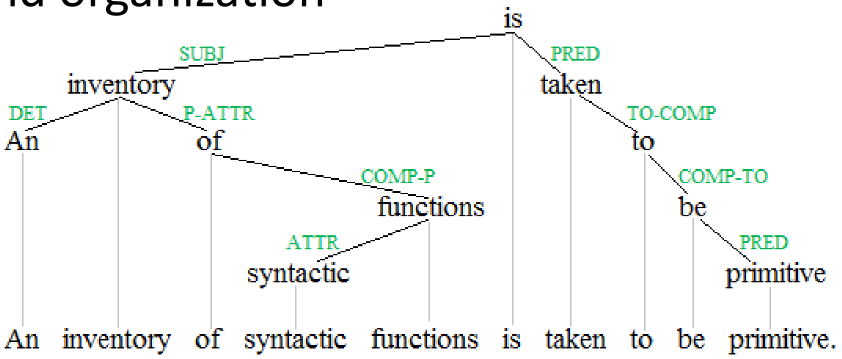
Terms	Documents													
	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14
abnormalities	0	0	0	0	0	0	0	1	0	1	0	0	0	0
age	1	0	0	0	0	0	0	0	0	0	0	1	0	0
behavior	0	0	0	0	1	1	0	0	0	0	0	0	0	0
blood	0	0	0	0	0	0	0	1	0	0	1	0	0	0
close	0	0	0	0	0	0	1	0	0	0	1	0	0	0
culture	1	1	0	0	0	0	0	1	1	0	0	0	0	0
depressed	1	0	1	1	1	0	0	0	0	0	0	0	0	0
discharge	1	1	0	0	0	1	0	0	0	0	0	0	0	0
disease	0	0	0	0	0	0	0	0	1	0	1	0	0	0
fast	0	0	0	0	0	0	0	0	0	1	0	1	1	1
generation	0	0	0	0	0	0	0	0	1	0	0	0	1	0
oestrogen	0	0	1	1	0	0	0	0	0	0	0	0	0	0
patients	1	1	0	1	0	0	0	1	0	0	0	0	0	0
pressure	0	0	0	0	0	0	0	0	0	0	1	0	0	1
rats	0	0	0	0	0	0	0	0	0	0	0	0	1	1
respect	0	0	0	0	0	0	0	1	0	0	0	1	0	0
rise	0	0	0	1	0	0	0	0	0	0	0	0	0	1
study	1	0	1	0	0	0	0	0	1	0	0	0	0	0

BagOfWord representation!

Automatic text indexing

- In modern search engine
  - **No** stemming or stopword removal, since computation and storage are no longer the major concern
  - More advanced NLP techniques are applied
    - Named entity recognition
      - E.g., people, location and organization
    - Dependency parsing

Query: "to be or not to be"



What you should know

- Basic techniques for crawling
- Zipf’s law
- Procedures for automatic text indexing
- Bag-of-Words document representation

Today's reading

- Introduction to Information Retrieval
  - Chapter 20: Web crawling and indexes
    - Section 20.1, Overview
    - Section 20.2, Crawling
  - Chapter 2: The term vocabulary and postings lists
    - Section 2.2, Determining the vocabulary of terms

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