Information retrieval I

Introduction : how to organize big data for efficient look-ups

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Mastère Big Data

October 17, 2018

Objectives of the course

- Acquire a culture in information retrieval
- Master the basics concepts allowing to understand:
    - what is at stake in novel IR methods
    - what are the technical limits

This will allow you to have the basics tools to analyze current limitations or lacks, and imagine novel solutions.

Today's outline

- What is information retrieval (in general)?
- Querying (correctness) and ranking (relevance)
- IR in the context of the web
  - Elements of web protocols and languages
  - Gathering data on the web: crawling
  - What data size is at stake?
- How to represent the information?
  - Indexing
  - Sparse representations
  - Reverse indexing
- Practicals: understanding and selling your patent!

What is information retrieval (IR)?

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Definition

Answering a query by extracting **relevant information** from **a collection of documents**.

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Typical example

Google.

What is "document" and "information"?

Information retrieval

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Here, **documents** are web pages, images, pdf, etc.

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How would you define **information** in the context of information retrieval?

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Information

Subset of documents relevant to a query.

What is "document" and "information"?

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Information

Subset of documents relevant to a query.

How could you qualify or measure information, e.g. relevance?

Correctness, relevance and truth

When was the last US presidential elections?

Correctness, relevance and truth

When was the last US presidential elections?

correct or **incorrect**

Correctness, relevance and truth

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- Blue
- 42:17

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true, **false** or**...**

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Relevance

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Relevance

- Same time as the previous ones, but 5 years later

Correctness, relevance and truth

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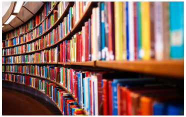
Relevance

- Same time as the previous ones, but 5 years later
- during the 21st Century
- 1478563200s since Unix Epoch[a]

[a] Number of seconds elapsed since 1st of January 1970

Querying and ranking systems



Collection of documents

$\downarrow$

Query $\longrightarrow$ Querying system

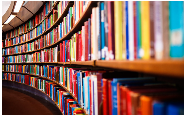
$\downarrow$

Correct answers

$\downarrow$

Ranking of answers (relevance)

Querying systems deal with correctness



Collection of documents

↓

Query ⟶ Querying system

↓

Correct answers

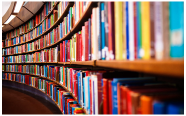
↓

Ranking of answers (relevance)

Filter documents that *correctly* answers a given query

- Boolean queries
  - Checks if a word is present or not in a document
- Probabilistic models
  - Naïve Bayes model
- Vector-based models

Ranking systems deal with relevance



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Ranking of answers (relevance)

Ranking methods:

- structure-agnostic algorithms
- unsupervised ranking
  - PageRank
- supervised ranking
  - machine learning

What are the pitfalls?

Exercise

Take few minutes to list what could be the different pitfalls for querying and ranking systems.

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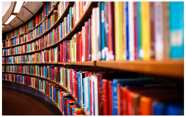
Exercise

Take few minutes to list what could be the different pitfalls for querying and ranking systems.

- Complexity of natural language
- Ambiguity of natural language
- Size of the data
- ...

IR specific to the World Wide Web

IR and the web



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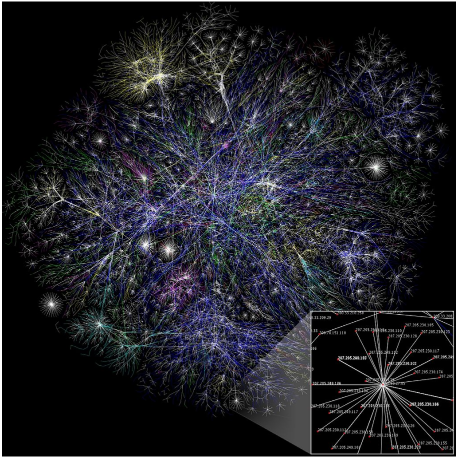
Ranking of answers (relevance)

2 specificities:

- Building the collection of documents
  - **Crawling** the web
  - **Indexing** documents
- Ranking the documents (next lecture)

Gathering data on the web (crawling)

The web structure: a huge graph



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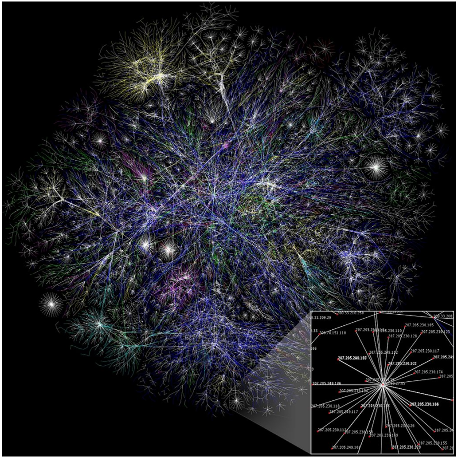
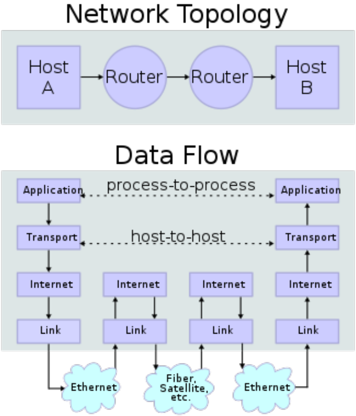


Initiated in 70's with ARPANET. In 2017, >8 Billion "nodes"

The web protocols



The textual web uses the HTTP[1] over TCP/IP protocol[2].

[1] T. Berners-Lee in 90 at CERN

[2] Cerf and Kahn, 74

The web structure: languages

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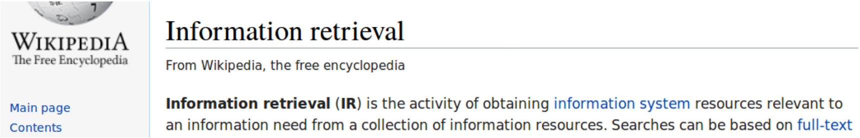

HTML source code behind:

```
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How would you collect information from the web?

The web structure: crawling

Hopping from link to link, one can collect/process data on the web:

Web crawling
JumpStation (1993)

⚠ Must keep track of already visited pages (e.g. trie).

Parsing links from a web page

With regular expressions (regex) for instance.

Regex	Match examples	
a*	aaa	a
M.x	Max	Mix
M.*x	Max	Matrix

Regex is a simple pattern matching formalism.

Regex: groups

Regex	data	1st group
M(.)x	Max	a
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Exercise

Find a regex that extracts the URL of an HTML link.

```
<a href="http://www.wikipedia.org">The linked text</a>
```

Extend your regex to extract both the URL and the linked text.

Quality of the data: HTML errors, difficult parsing.

What is the size of the crawled data?

Quizz:

Number of pages indexed by Google	
Data size crawled by Google	
Number of pages with k/2 incoming links	
Number of pages of length L/2	

[3] [Pandya et al. IJIRST 2017]

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6 degrees of separation law.

Between 0.2% and 4% of the web is accessible by crawling[3].
What is "uncrawlable" is coined the **deep web**.

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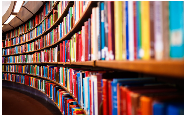
From gathering to representation



Collection of documents

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Query $\longrightarrow$ $\boxed{\text{Querying system}}$

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Correct answers

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Ranking of answers
(relevance)

Representations of a web document

How to query for correct documents?

Exercise

Take few minutes to think how you would retrieve the web documents corresponding to the query:

`result last elections president united states`

How to query for correct documents?

Exercise

Take few minutes to think how you would retrieve the web documents corresponding to the query:

```
result last elections president united states
```

You may have encounter the following issues:

- how to correctly match words in the document (tokenization)
- how to match equivalent word (e.g. plural)
- how to implement it

Tokenization

Process of chopping the text of a document in atomic elements:

Brian is in the kitchen $\rightarrow$ <u>Brian</u> <u>is</u> <u>in</u> <u>the</u> <u>kitchen</u>

Tokenization

Process of chopping the text of a document in atomic elements:

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Usually, tokenizers remove the punctuation.

May be difficult: `United States` $\neq$ `United + States`!

- Data mining approaches help to extract the right tokens: if two words are significantly seen one after the other, may be consider as a token.
- Some languages are agglutinative (e.g. Turkish).

Stemming

Language-specific rules defining equivalent words up to a usual transformation (e.g. -ing, -ed, -s, etc.).
For instance, we would transform:

plural forms:	elections	$\rightarrow$	election
substantive/adjectival forms:	presidential	$\rightarrow$	president
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Again, same difficulties could appear:

- ambiguity: police, policy $\rightarrow$ polic
- Non-conflating: mother, maternal

Naive representation: vector of tokens

Matrix with the occurence of tokens in documents.

	tok 1	tok 2	tok 3	tok 4	tok 5	...
	election	president	crazy	united	United States	...
doc 1	1	1	0	0	1	...
doc 2	0	1	1	0	1	...
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...	...	...	...	...	...	...

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Write down a simple algorithm that extracts given a doc-tok matrix the documents matching a query.

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Can you foresee any practical problem? What is the size of the matrix?
Can it fit in **memory**?

Sparse representation

Since documents contain only a small fraction of existing tokens, most of the vector of token entries are null.
We can use a sparse encoding of the same information:

tok 1	tok 2	tok 3	tok 4	tok 5
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doc 1→tok 1, tok 2, tok 5
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What is the size of the sparse encoding data structure?

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Hmmm

Write an algorithm extracting the matching documents from a sparse encoding doc-tok.

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Write an algorithm extracting the matching documents from a sparse encoding doc-tok.**How long** would it take to process a query?

Elements in complexity

Definition

The complexity is the measure the of the size an algorithm needs of memory and the time it takes to process.

It is usually measured in terms of order of magnitude of the size of the input data.

[4] k can be related to the length of the document through Heap's law: $k = K.L^{\beta}$. In practice, $K = 50, \beta = 0.5$

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Can we do better?

[4] k can be related to the length of the document through Heap's law: $k = K.L^{\beta}$. In practice, $K = 50, \beta = 0.5$

Elements in complexity: sorting

Action	Complexity
Accessing an element of a matrix	$\mathcal{O}(1)$
Sorting	$\mathcal{O}(N \log N)$
Searching a sorted list	$\mathcal{O}(\log N)$

Exercise

Imagine a way of improving how to query a big set of documents.

Inverse sparse index

Idea

Inverting the sparse representation and sorting by document allows to reduce the complexity.

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tok 2→doc 1,doc 2,doc 3,...
tok 3→doc 2,doc 3,...
tok 4→doc 102,...
tok 5→doc 1,doc 2,doc 3,...

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Exercise

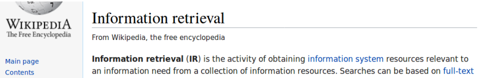
Write an algorithm that indexes a document using a reverse sparse index.
Compute the time complexity for querying an inverse sparse index.

Building an inverted index in practice

The full sparse index does not fit in memory.
Block Sort-Based Indexing is a simple algorithm allows to invert big dictionaries that do not fit in main memory, at low cost, and that can even be parallelized[5].

[5] https://westmont.instructure.com/files/51060/download?download_frd=1

Summary

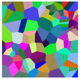

WIKIPEDIA
The Free Encyclopedia

Main page
Contents

Information retrieval

From Wikipedia, the free encyclopedia

Information retrieval (**IR**) is the activity of obtaining information system resources relevant to an information need from a collection of information resources. Searches can be based on full-text



Glimpse of next week: the boolean queries are not flexible

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Query: `result elections United States`
Doc title: "White House election: live results!"

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Any solution?

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Any solution?

- Use semantics (ontologies)
- Next week: Use query expansion (add related terms to the query)
- Next week: Use a more flexible querying system

Glimpse of next week: the boolean queries do not rank

Example

Query: `result elections United States`
matching results: 718,698,789

How to pick up most relevant results first?

- Next week: With more complex querying and representation of the information
- Next week: By exploiting the graph structure of the web (Google)

Extras

How to store already crawled URLs?

Exercise

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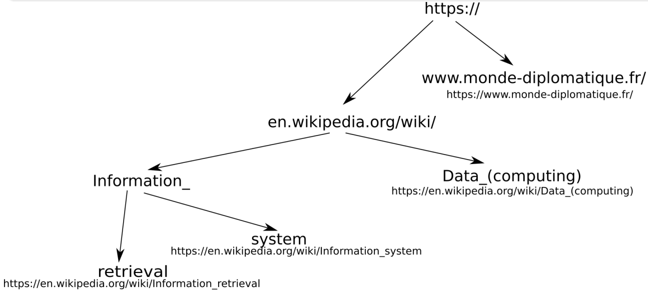

A *trie* structure.

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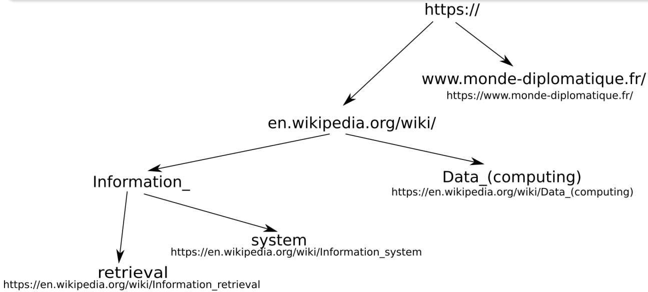

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Exercise

What is the complexity in time?

Examples of (successful) companies in IR

ElasticSearch	Distributed, RESTful[6] search and analytics engine capable of solving a growing number of use cases. [...] centrally stores your data so you can discover the expected and uncover the unexpected.
swiftype	All-in-one relevance, lightning-fast setup and unprecedented control.
blekko	Now in IBM Watson

[6] i.e. based on HTTP