

Introduction to Information Retrieval

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Outline

- ① The Big Picture
- ② Indexing
- ③ Preprocessing and Models
 - Document Analysis and (Pre-)Processing
 - Boolean Model
 - Term Weighting
 - Vector Space Model
- ④ Evaluation
- ⑤ Web Search
- ⑥ Multimedia Information Retrieval
- ⑦ Using Semantics and the Web of Data

Outline

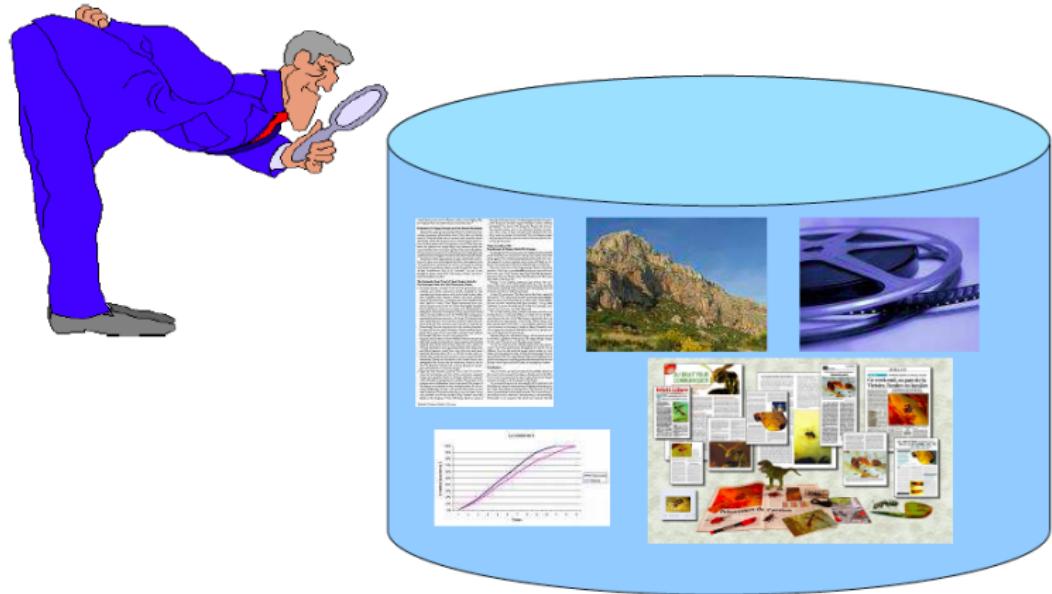
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What is information retrieval?

An information retrieval system (IRS) is a system that allows to discover **meaningful and useful** information with respect to a **query** in a big collection of documents.

- Structured: Relational databases (*data retrieval*)
- Unstructured: text, video, sound (*information retrieval*)

What is information retrieval?



From a course by C. Hudelot

Goal of this course

Answer the questions:

- What is the theory behind an IRS?
- How to measure the efficiency of an IRS?
- What is hiding behind a web search engine?
- Where IR ends and where Data Mining begins?
- What are the current challenges?

Introduction

When and where do we have to do with IR?

- Everyday activity of every person who goes on the Internet

Important concepts:

- A document: a wikipedia web page, a tweet, an image,...
- A query: an expression of a certain information need of the user

Introduction

Bjork

Web Images Maps Shopping Vidéos Plus + Outils de recherche

Environ 3 760 000 résultats (0,20 secondes)

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OK En savoir plus

bjork.com
bjork.com/ Traduire cette page

as you may have noticed, things have changed around here. we're exploring new worlds, which some of you might have heard of, starting with biophilia, björk's ...

[Björk - Wikipédia](http://fr.wikipedia.org/wiki/Björk)
fr.wikipedia.org/wiki/Björk

Björk Guðmundsdóttir ([pjɔrk 'kvðm̥vntɪs, toðhtɪr]) est une musicienne, chanteuse, compositrice et actrice islandaise, née le 21 novembre 1965 à ...
Goldie - Matthew Barney - Discographie de Björk - Vidéographie de Björk
Vous avez consulté cette page 3 fois. Dernière visite : 28/12/13

bjork.fr - Le site francophone sur Björk
www.bjork.fr -
Une communauté francophone dédiée à la chanteuse et aux musiques islandaises propose des forums de discussion, des actualités et des séquences vidéo.

[Björk - AlloCiné](http://www.allocine.fr/Stars/Toutes les stars/Islande)
www.allocine.fr/Stars/Toutes les stars/Islande

Björk (Björk Guðmundsdóttir), Actrice, Compositeur. Découvrez sa biographie, sa carrière en détail et toute son actualité.

[Björk | Listen and Stream Free Music, Albums, New Releases ...](https://myspace.com/bjork)
https://myspace.com/bjork

Björk's profile including the latest music, albums, songs, music videos and more updates.

[Björk - It's Oh So Quiet - YouTube](https://www.youtube.com/watch?v=htobTBICvUU)
www.youtube.com/v/htobTBICvUU
1 juil. 2007 - Ajouté par bjorkdotcom

 Plus d'images

Björk

1 645 431 abonnés sur Google+

Björk Guðmundsdóttir est une musicienne, chanteuse, compositrice et actrice islandaise, née le 21 novembre 1965 à Reykjavík. [Wikipedia](#)

Conjoint : [Matthew Barney](#)
Conjoint : [Pór Elton](#) (m. 1986–1987)
Films : [Dancer in the Dark](#), [Drawing Restraint 9](#), [Prêt-à-porter](#), [Plus](#)

Titles

All Is Full of Love	1997	Homogenic
It's Oh So Quiet	1995	Post
Army of Me	1995	Post
Moon	2011	Biophilia
Hidden Place	2001	Vespertine

Posts récents

 * I'm not gonna do the same stuff again , because if I did I'd be bored shiitess . "source:
<http://bit.ly/18CQ0n5> 20 déc. 2013

Introduction

Important concepts: **relevance**

A relevant document is that which contains the researched information.

- difficulty: the researched information corresponds to an **information need** which is expressed by a **query**
- the relevance can be used to evaluate the quality of an IRS

Important concepts: **user feedback**

- active user involvement
- user profile

Introduction

jaguar

Web Images Maps Shopping Plus Outils de recherche

Environ 74 000 000 résultats (0,27 secondes)

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OK En savoir plus

Jaguar France - Voitures de Sport et Voitures de luxe
www.jaguar.fr/ ▾

Découvrez les voitures de luxe Jaguar. Alliant héritage et technologie, les berlines et voitures de sport Jaguar vous feront vivre une expérience de conduite ...

Images correspondant à jaguar - Signaler des images inappropriées



Jaguar - Wikipédia
fr.wikipedia.org/wiki/Jaguar ▾

Statut de conservation UICN. (NT) NT : Quasi menacé. Statut CITES. Sur l'annexe I de la CITES Annexe I , Rév. du 01-07-1975. Le jaguar (*Panthera onca*) est ...

Jaguar (automobile) - Wikipédia
[fr.wikipedia.org/wiki/Jaguar_\(automobile\)](http://fr.wikipedia.org/wiki/Jaguar_(automobile)) ▾

Jaguar, de son nom officiel « Jaguar Cars Ltd », est une marque automobile connue pour ses voitures de luxe et ses modèles sportifs. La marque est la propriété de l'indien Tata Motors depuis 2008. [Wikipedia](#)

Jaguar
Automobile



Jaguar, de son nom officiel « Jaguar Cars Ltd », est une marque automobile connue pour ses voitures de luxe et ses modèles sportifs. La marque est la propriété de l'indien Tata Motors depuis 2008. [Wikipedia](#)

Date de fondation : 1922
PDG : Ralf Speth
Fondateurs : William Walmsley, William Lyons

Signaler un problème/Plus d'infos

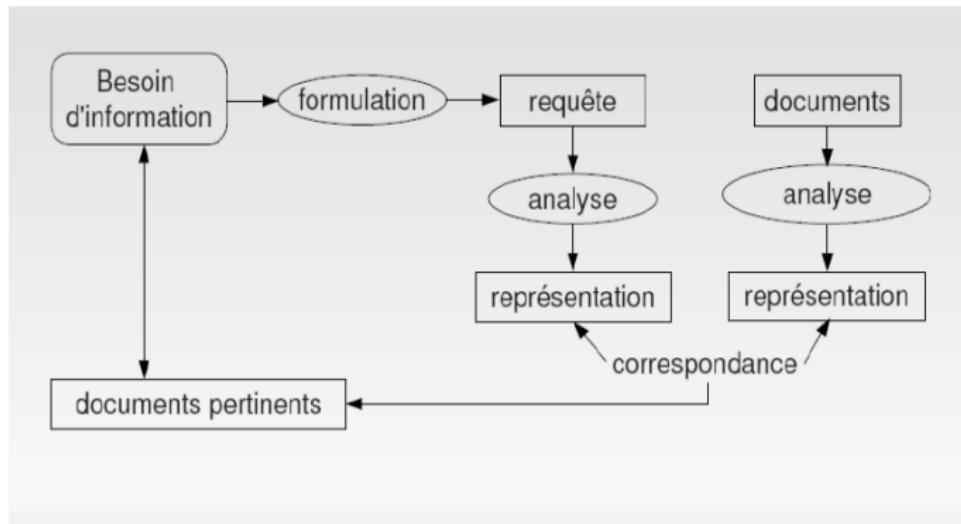
Afficher les résultats pour

Jaguar (Animal)
Le jaguar est un mammifère carnivore de la famille des félidés. C'est l'un des cinq « grands félins » du ...



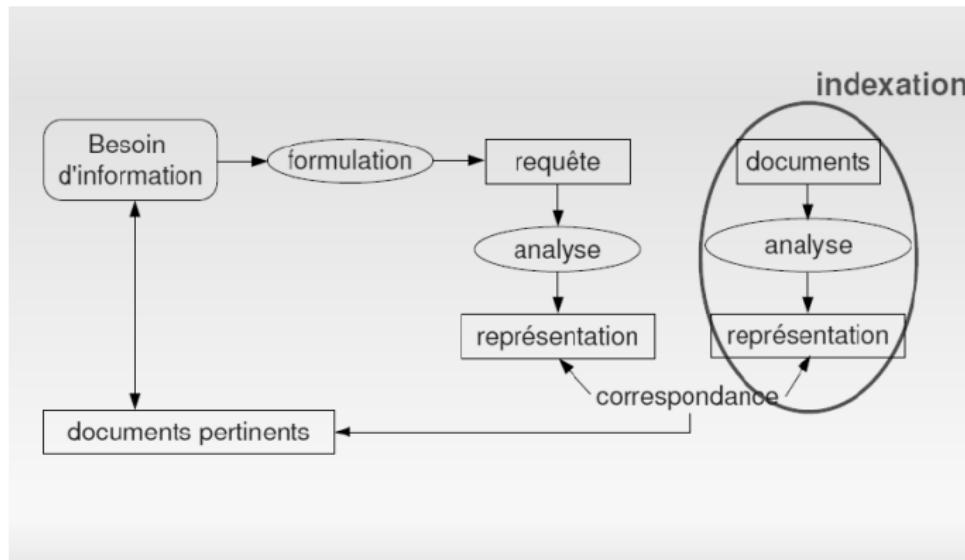
Introduction

The classical approach to information retrieval



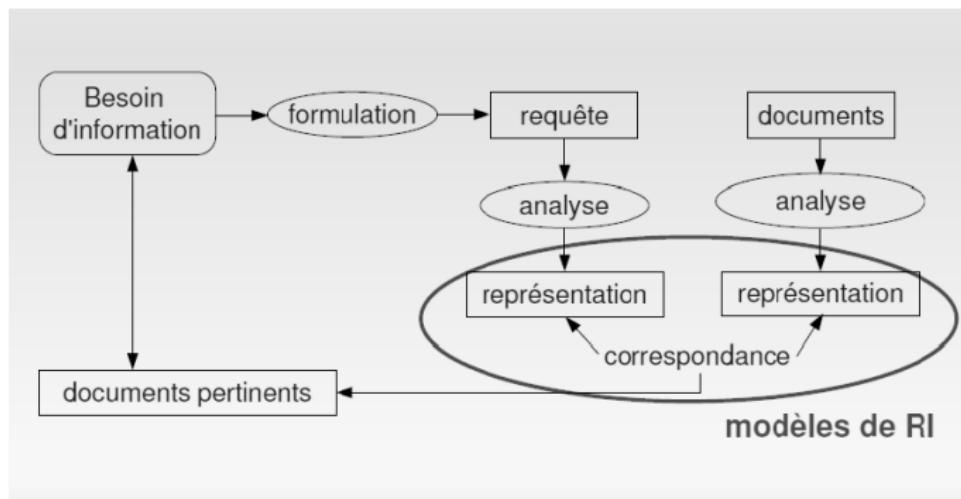
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The classical approach to information retrieval: **indexing**



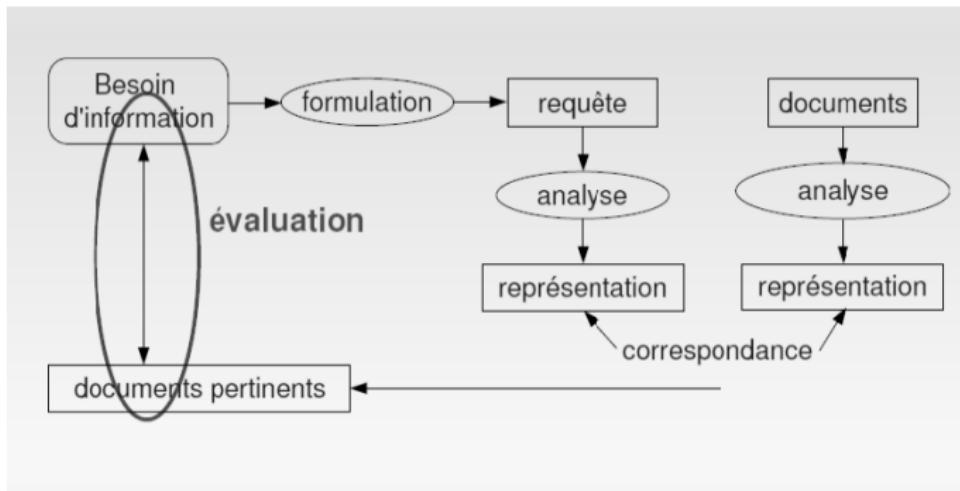
Introduction

The classical approach to information retrieval: **models**



Introduction

The classical approach to information retrieval: **evaluation**



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Indexing

- **Index:** a data structure built from text to speed up the search by providing an appropriate representation of the documents.
- When a text collection is **updated**, the index has to be updated, too.
- **Semi-static collections:** collections which are updated at reasonable regular intervals (say, daily)
- Most real text collections, including **the Web**, are indeed semi-static
Although the Web changes very fast, the crawls of a search engine are relatively slow

Indexing

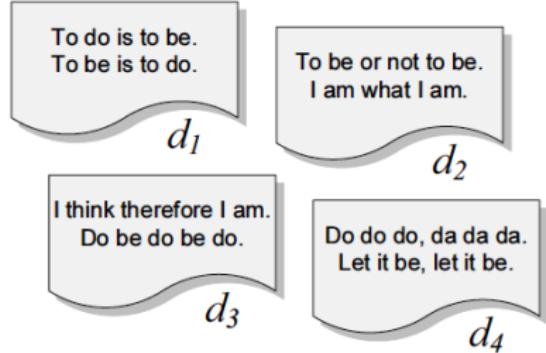
Basic concepts

- **Inverted index**: a word-oriented mechanism for indexing a text collection to speed up the searching task
- The inverted index structure is composed of two elements: **the vocabulary** and **the occurrences**
- The vocabulary is the set of all different words in the text
- For each word in the vocabulary the index stores the documents which contain that word (inverted index)

Indexing

Term-document matrix

Vocabulary	n_i	d_1	d_2	d_3	d_4
to	2	4	2	-	-
do	3	2	-	3	3
is	1	2	-	-	-
be	4	2	2	2	2
or	1	-	1	-	-
not	1	-	1	-	-
I	2	-	2	2	-
am	2	-	2	1	-
what	1	-	1	-	-
think	1	-	-	1	-
therefore	1	-	-	1	-
da	1	-	-	-	3
let	1	-	-	-	2
it	1	-	-	-	2



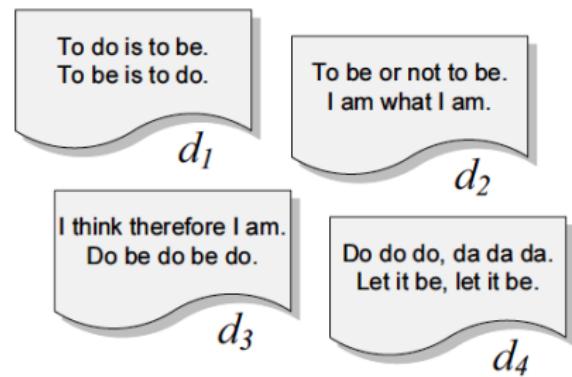
Taken from Baeza-Yates and Ribeiro-Neto.

Indexing

Inverted index (basic form)

Limit the required space for storing

Vocabulary	n_i	Occurrences as inverted lists
to	2	[1,4],[2,2]
do	3	[1,2],[3,3],[4,3]
is	1	[1,2]
be	4	[1,2],[2,2],[3,2],[4,2]
or	1	[2,1]
not	1	[2,1]
I	2	[2,2],[3,2]
am	2	[2,2],[3,1]
what	1	[2,1]
think	1	[3,1]
therefore	1	[3,1]
da	1	[4,3]
let	1	[4,2]
it	1	[4,2]



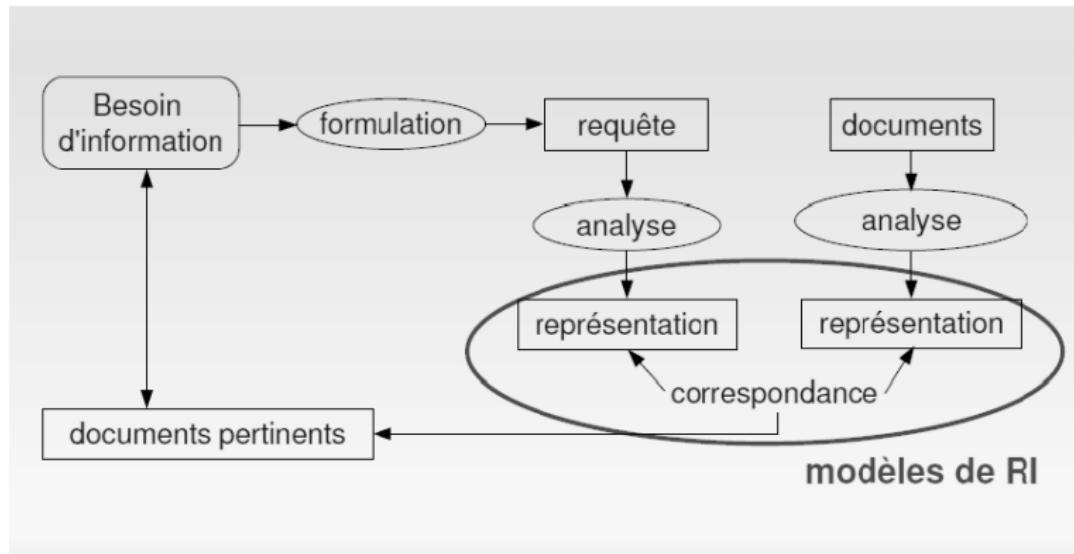
Taken from Baeza-Yates and Ribeiro-Neto.

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The classical approach to information retrieval: **models**



Models

A model is a mathematical abstraction of a real process which helps to study and predict the behavior of a system.

Modeling in IR consists of two main tasks:

- The conception of a logical framework for representing documents and queries
- The definition of a ranking function that allows quantifying the similarities among documents and queries

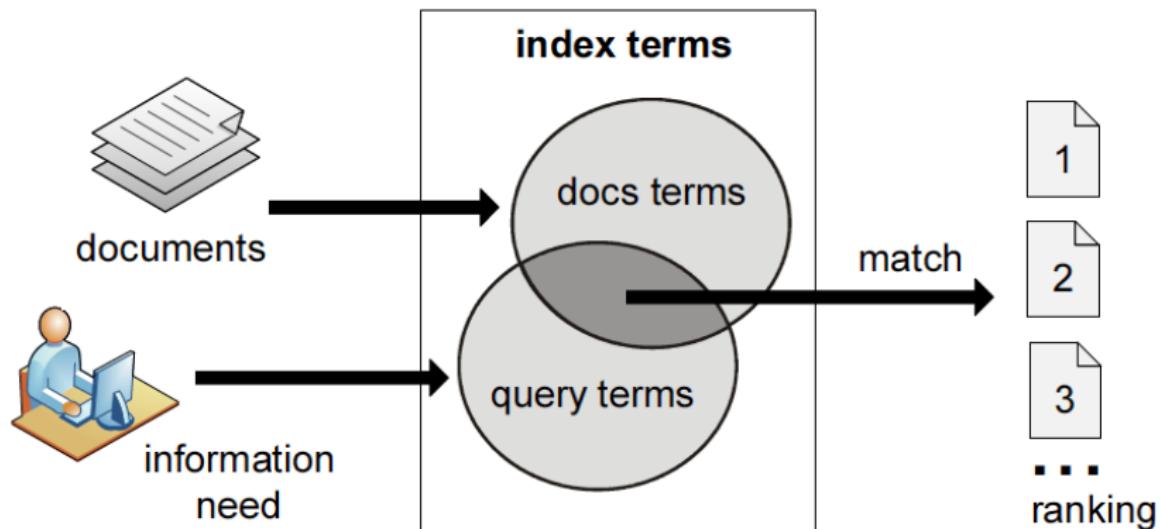
Models

IR systems use the *index terms* to retrieve documents

- Index term (terms from the vocabulary of the index):
 - In a restricted sense: it is a **keyword** that has some meaning on its own; usually plays the role of a noun
 - In a more general form: it is any word that appears in a document
- Retrieval based on index terms can be **implemented efficiently** (see Indexing section)
- Index terms are simple to **refer to** in a query

Models

The IR process

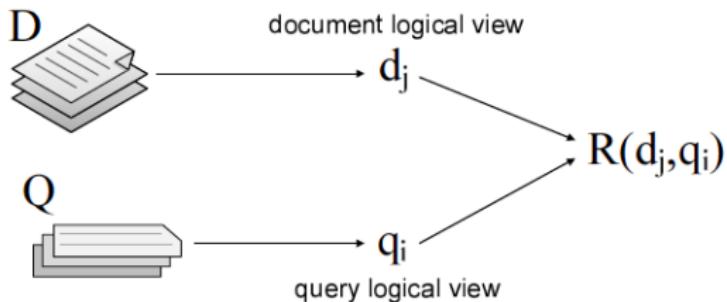


Taken from Baeza-Yates and Ribeiro-Neto.

Models

An **IR model** is a quadruple $[D, Q, \mathcal{F}, R(q_i, d_j)]$ where

1. D is a set of logical views for the documents in the collection
2. Q is a set of logical views for the user queries
3. \mathcal{F} is a framework for modeling documents and queries
4. $R(q_i, d_j)$ is a ranking function



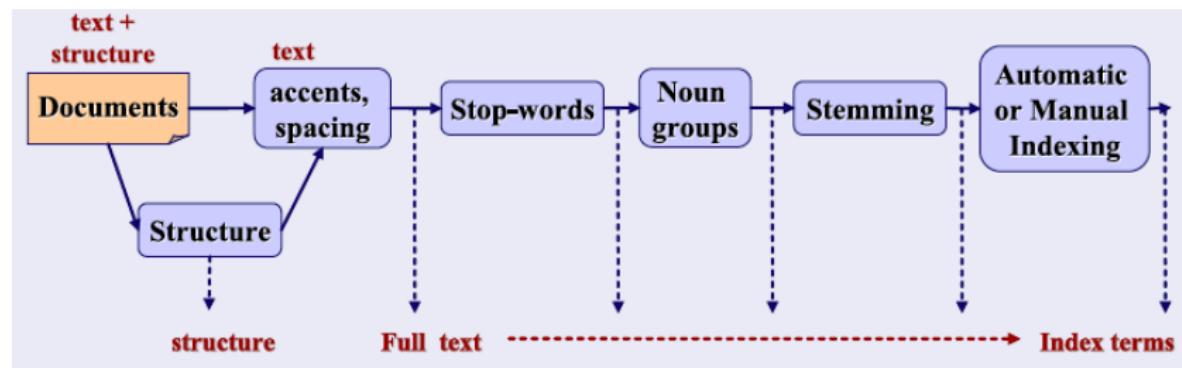
Taken from Baeza-Yates and Ribeiro-Neto.

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Document Processing

Representation of a document: a logical view



From full text —————-> to a set of index terms

Document Processing

Representation of a document: preprocessing

- **Stop words:** articles, conjunctions, too frequent (common) words,...
specific to a language: "the", "a", "and", "her",...
- **Noun groups:** remove adjectives, verbs, adverbs
- **Stemming / Lemmatization:** strip words down to their canonical forms
{"computers", "computing", "computation"} -> "comput"

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Boolean Model

The simplest model based on **set theory** and **exact matches**.

- The term-document matrix contains only **zeros and ones**: 0 if a term is not found in a document, 1 - otherwise
- Documents are returned if they satisfy a given **boolean expression**: a query is given as a set of index terms connected by logical operators AND, OR, NOT
- The results are **non-ordered**: a document is **either relevant or not** (to a query)

Boolean Model

Boolean truth tables

a	b	not $\neg b$	and $a \wedge b$	or $a \vee b$
0	0	1	0	0
0	1	0	0	1
1	0		0	1
1	1		1	1

For x, y, c, d index terms, a query:

- $x \text{ AND } y ?$
- $(x \text{ AND } y) \text{ OR } c \text{ AND NOT } d ?$

Boolean Model

An example

	Anthony and Caesar	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth
Cleopatra						
Anthony	1	1	0	0	0	1
Brutus	1	1	0	1	0	0
Caesar	1	1	0	1	1	1
Calpurnia	0	1	0	0	0	0
Cleopatra	1	0	0	0	0	0
mercy	1	0	1	1	1	1
worser	1	0	1	1	1	0

Boolean Model

An example

	Anthony and Cleopatra	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth
Anthony	1	1	0	0	0	1
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Caesar	1	1	0	1	1	1
Calpurnia	0	1	0	0	0	0
Cleopatra	1	0	0	0	0	0
mercy	1	0	1	1	1	1
worser	1	0	1	1	1	0

Query:

Brutus AND Caesar AND NOT Calpurnia

Boolean Model

An example

	Anthony and Cleopatra	Julius Caesar	The Tempest	Hamlet	Othello	Macbeth
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Calpurnia	0	1	0	0	0	0
Cleopatra	1	0	0	0	0	0
mercy	1	0	1	1	1	1
worser	1	0	1	1	1	0

Query: Brutus AND Caesar AND NOT Calpurnia

Boolean expression: 110100 AND 110111 AND 101111 = 100100

Results for this query...?

Boolean Model

Drawbacks of this model

- No notion of partial matching
- No ranking (absence of a grading scale)
- The query is given as a Boolean expression
 - > the user has to know how to do that!
- The Boolean queries formulated by the users are most often too simplistic
- The model frequently returns either too few or too many documents

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Term Weighting

Motivation

- The terms of a document are *not equally "useful"* for describing the document content
- Some index terms carry more information than others
- There are properties of an index term which are useful for evaluating the importance of the term in a document

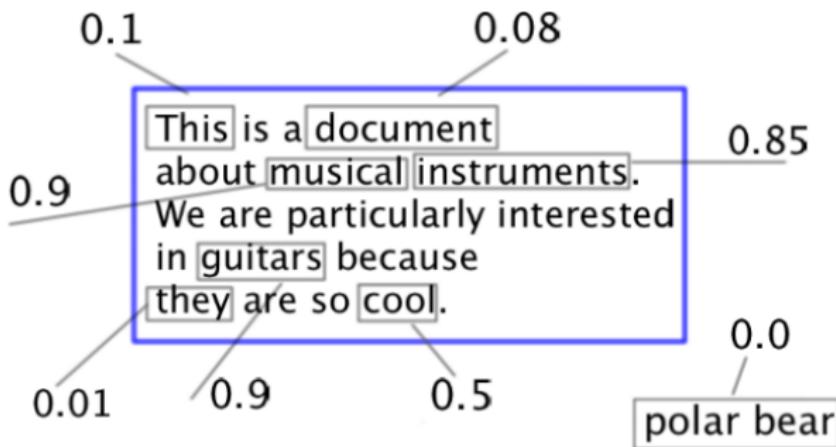
Important or unimportant?

- A word which appears in all documents of a collection?
- A word that appears in only 1 document, several times?

Term Weighting

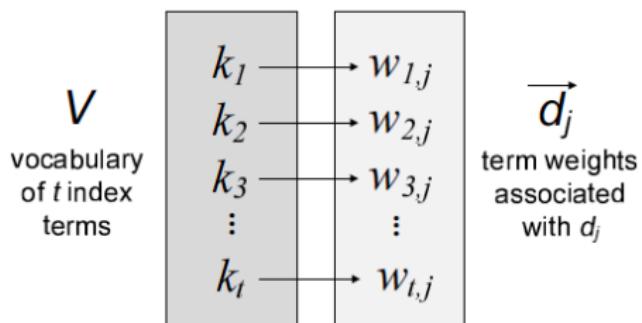
We associate a **weight** to every term with respect to a document:

- a term k_i
- a document d_j
- a weight $w_{i,j} \geq 0$



Term Weighting

Let $V = (k_1, k_2, \dots, k_t)$ be the vocabulary (the set of all index terms)



We can express a document as a vector: $\mathbf{d}_j = (w_{1,j}, w_{2,j}, \dots, w_{t,j})$.
(We will see that in detail in the vector model.)

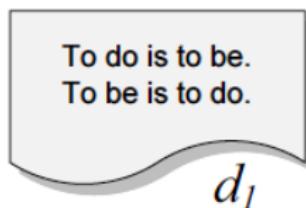
Term Weighting

How to set these weights ?

Term Weighting

- Boolean model: $w_{i,j} \in \{0, 1\}$.

A term k_i has a weight 1 in document d_j if it appears (at least once) in d_j .



$$w_{do,1} = w_{to,1} = 1$$

Term Weighting

- **Term frequency**: the number of times a term appears in a document, $f_{i,j}$
- **Total term frequency**: the number of times a term appears in the whole collection, F_i
- **Document frequency**: the number of documents a term appears in, n_i

Example: the term "do"

$$f(\text{do}, d_1) = 2$$

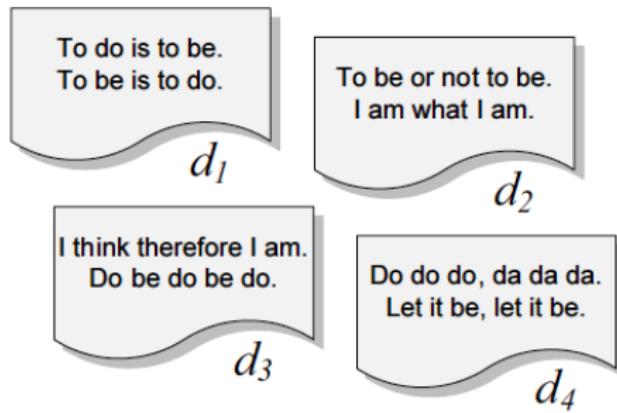
$$f(\text{do}, d_2) = 0$$

$$f(\text{do}, d_3) = 3$$

$$f(\text{do}, d_4) = 3$$

$$F(\text{do}) = 8$$

$$n(\text{do}) = 3$$



Term Weighting

- The TF-IDF weighting rule

Allows to take into account the importance of a term within a document, as well as throughout the whole collection.

TF-IDF = Term frequency - Inverse document frequency

For a collection of N documents:

$$IDF(k_i) = \log \frac{N}{DF(k_i)}.$$

IDF diminishes the weight of words that appear too often in the whole collection.

So, we have:

$$TF\text{-}IDF_{i,j} = TF_{i,j} \times IDF_i$$

Document Length Normalization

- Documents are of different sizes
- Longer documents -> more likely to be retrieved!!
- The rank of each document should be penalized (divided) by its length

In the case of vector representation (e.g., with TF-IDF weights) the length of a document is given by the vector norm.

$$\mathbf{d}_j = (w_{1,j}, w_{2,j}, \dots, w_{t,j})$$

$$|\mathbf{d}_j| = \sqrt{\sum_{k=1}^t w_{k,j}^2}$$

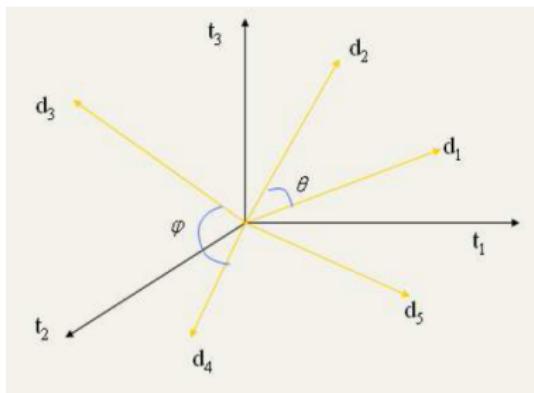
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Vector Space Model

Documents are represented as **vectors** in a common vector space.

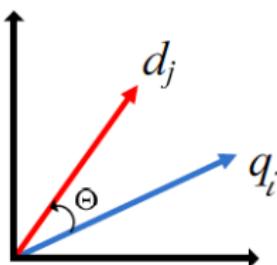
- Index terms = axes (dimensions) of the vector space
- Index terms are assumed to be **independent**
- The value of a given dimension for a given document corresponds to the weight of the corresponding term that defines that dimension



All documents "live" in the same vector space, same dimension, t .

Vector Space Model

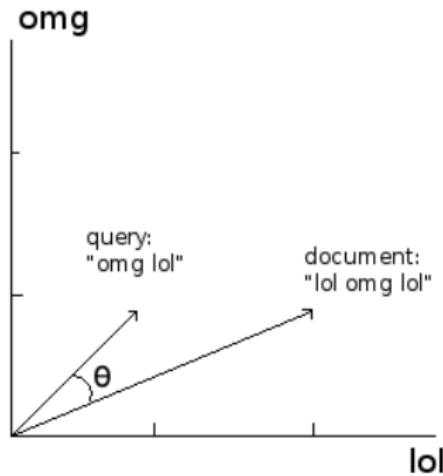
But also: the query is represented as a vector in the same vector space as the documents !



$$\mathbf{d}_j = (w_{1,j}, w_{2,j}, \dots, w_{t,j}), \mathbf{q}_i = (w_{1,i}, w_{2,i}, \dots, w_{t,i})$$

Vector Space Model

Example in 2 dimensions:



Now we can measure **similarities and distances** between documents and between a query and a document.

Vector Space Model

A common similarity measure: **the cosine**.

$$\cos(\theta) = \frac{\mathbf{d}_j \times \mathbf{q}_i}{\|\mathbf{d}_j\| \|\mathbf{q}_i\|}$$

In a given weighting scheme, we have:

$$sim(\mathbf{d}_j, \mathbf{q}_i) = \frac{\sum_{k=1}^t w_{k,j} \times w_{k,i}}{\sqrt{\sum_{k=1}^t w_{k,j}^2} \times \sqrt{\sum_{k=1}^t w_{k,i}^2}}$$

Vector Space Model

Pros

- Allows to use term weights. This improves the quality of the results
- Retrieve documents which partially correspond to a query
- A natural ranking scheme based on the cosine similarity
- Document length normalization is built-in the ranking function

Cons

- Term independence assumption

Vector Space Model: an Example

Documents:

d_1 : "new york times"

d_2 : "new york post"

d_3 : "los angeles times"

The IDF values of the terms:

$$idf(\text{angeles}) = \log(3/1) = 1.584$$

$$idf(\text{los}) = \log(3/1) = 1.584$$

$$idf(\text{new}) = \log(3/2) = 0.584$$

$$idf(\text{post}) = \log(3/1) = 1.584$$

$$idf(\text{times}) = \log(3/2) = 0.584$$

$$idf(\text{york}) = \log(3/2) = 0.584$$

Vector Space Model: an Example

TF matrix:

	angeles	los	new	post	times	york
d1	0	0	1	0	1	1
d2	0	0	1	1	0	1
d3	1	1	0	0	1	0

TF-IDF matrix:

	angeles	los	new	post	times	york
d1	0	0	0.584	0	0.584	0.584
d2	0	0	0.584	1.584	0	0.584
d3	1.584	1.584	0	0	0.584	0

Vector Space Model: an Example

Query: q : "new new times"

We compute the tf-idf's of every term in the query and then the

Query TF-IDF matrix:

q	0	0	2 *0.584=1,168	0	1 *0.584=0.584	0
---	---	---	----------------	---	----------------	---

Compute the length of the documents and the query:

$$|d_1| = \sqrt{(0.584^2 + 0.584^2 + 0.584^2)} = 1.011$$

$$|d_2| = 1.786$$

$$|d_3| = 2.316$$

$$|q| = 0.652$$

Vector Space Model: an Example

Finally, calculate the cosine similarities between the query and each document:

$$\text{cosSim}(d1, q) = (0*0+0*0+0.584*0.584+0*0+0.584*0.292+0.584*0) / (1.011*0.652) = 0.776$$

$$\text{cosSim}(d2, q) = (0*0+0*0+0.584*0.584+1.584*0+0*0.292+0.584*0) / (1.786*0.652) = 0.292$$

$$\text{cosSim}(d3, q) = (1.584*0+1.584*0+0*0.584+0*0+0.584*0.292+0*0) / (2.316*0.652) = 0.112$$

With respect to the similarity values, return the documents in the following order:

d_1

d_2

d_3

Models

Many more...

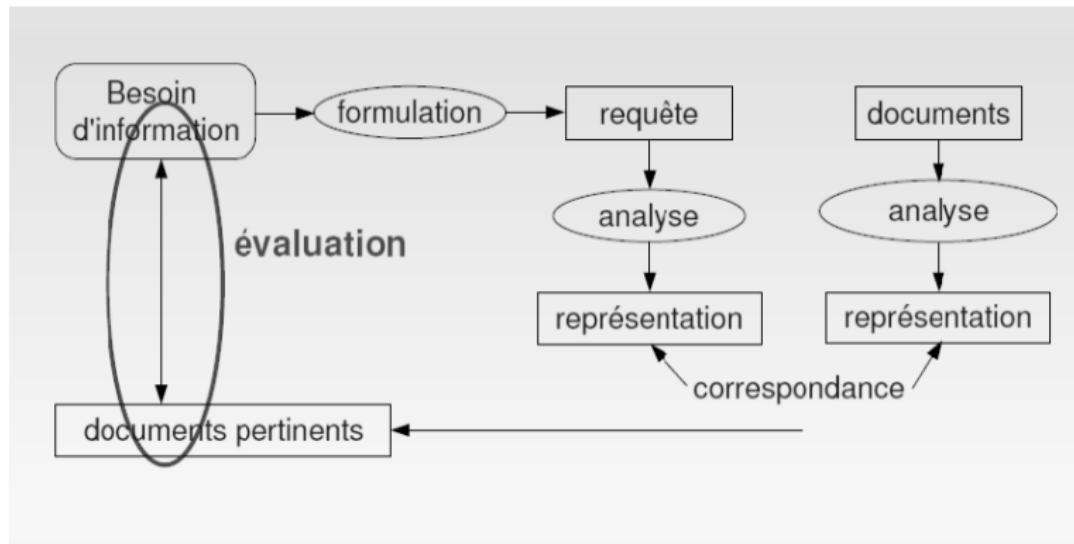
- Probabilistic model
- Fuzzy set theoretic model
- ...

Outline

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- ⑤ Web Search
- ⑥ Multimedia Information Retrieval
- ⑦ Using Semantics and the Web of Data

Introduction

The classical approach to information retrieval: **evaluation**



Evaluation

The quality of an IRS depends on many factors.

- Many different models, algorithms: which one is the best for my needs?
- Many different parameters within each model (similarity measure, term selection, term-weights): how to set these parameters?

The answers are an outcome of an empirical study.

Evaluation

Relevance of the results: depends on the user's satisfaction wrt. her information need.

Given a set of results: different groups of users => different degrees of satisfaction

Types of users:

- Web
- Enterprise
- Client/Vendor

Types of usage:

- Search to learn: "*The effect of global warming*"
- Search of a precise fact: "*The capital of Brazil*"
- Search of related information: "*Books about Montpellier*"

Evaluation

Exemple

- Besoin d'information : *Est ce que boire du vin rouge est plus efficace que le vin blanc concernant la réduction de risques au niveau du cœur ?*
- Requête : VIN ET ROUGE ET BLANC ET RISQUE ET COEUR ET EFFICACE

Exemple de document

Il s'est lancé dans le cœur de son discours et il a attaqué l'industrie viticole concernant sa sous-évaluation des risques du vin blanc et du vin rouge pour la conduite sous l'influence de drogues

Perfect match between a query and a document. OK ?...

The evaluation has to be done with respect to the information need and not to the query!

Evaluation

Measure the performance of an IRS:

we need a **quantitative metric** associated to the results produced by an IR system

In a reply to a given query, an IRS returns an **ordered list** of documents

- The order of the returned documents has to reflect their **degree of relevance** to the information need
- How to measure **relevance** (different models) -> how to evaluate the quality of the returned results

Evaluation

Classical **ground truth** methodology:

- A set of documents
- A set of queries
- A relevance judgement: a measure for every pair (document, query)

A bit of history: the Cranfield initiative (1950s):

- Experiments on manually collected documents
- Study of 2 quantities: the fraction of relevant documents retrieved, and the fraction of retrieved documents that are relevant
- First insights, first test **reference collection**

Evaluation

Reference Collection

Reference collections, which are based on the foundations established by the Cranfield experiments, constitute the most used evaluation method in IR

A reference collection is composed of:

- A set \mathcal{D} of pre-selected documents
- A set \mathcal{I} of information need descriptions used for testing
- A set of relevance judgements associated with each pair $[i_m, d_j]$,
 $i_m \in \mathcal{I}$ and $d_j \in \mathcal{D}$

The relevance judgement has a value of 0 if document d_j is non-relevant to i_m , and 1 otherwise

These judgements are produced by human specialists

Evaluation

Precision and Recall

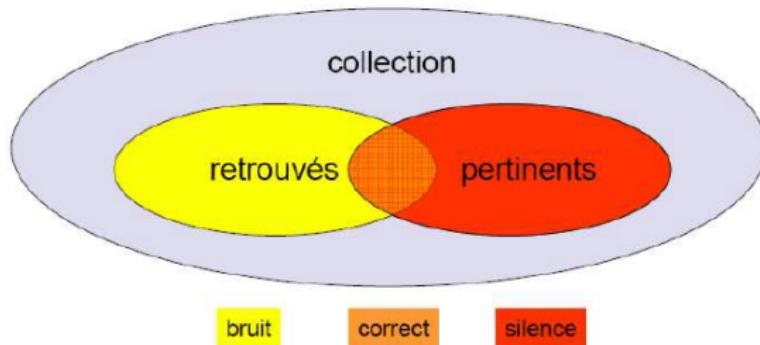
We can partition the documents in 4 categories:

	Relevant	Nonrelevant
Retrieved	tp	fp
Not Retrieved	fn	tn

tp = true positives, **fp** = false positives **tn** = true negatives, **fn** = false negatives

Evaluation

Precision and Recall



Precision and Recall

$$P = \frac{\text{relevant_found}}{\text{all_found}}, \quad R = \frac{\text{relevant_found}}{\text{all_relevant}}.$$

Evaluation

Precision and Recall

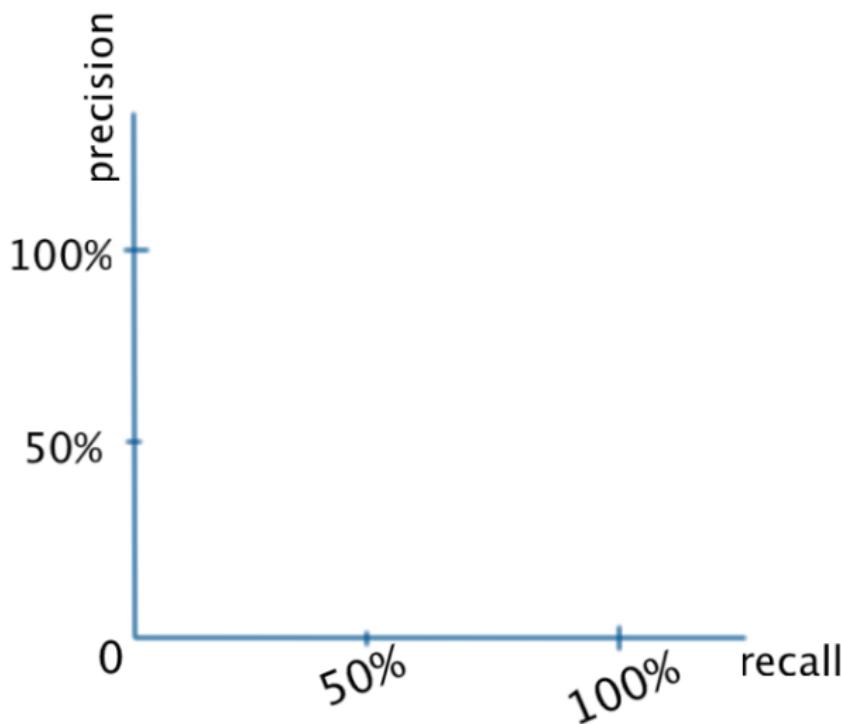
Some observations

- The definitions of precision and recall are based on the whole set of found documents
- The user is usually not presented with the whole set of found documents
- User goes through a ranked list of documents, examining them one by one, starting from the top
- Precision and recall change as the user advances in the list of found documents

Therefore, it is convenient to plot a curve showing the evolution of P and R

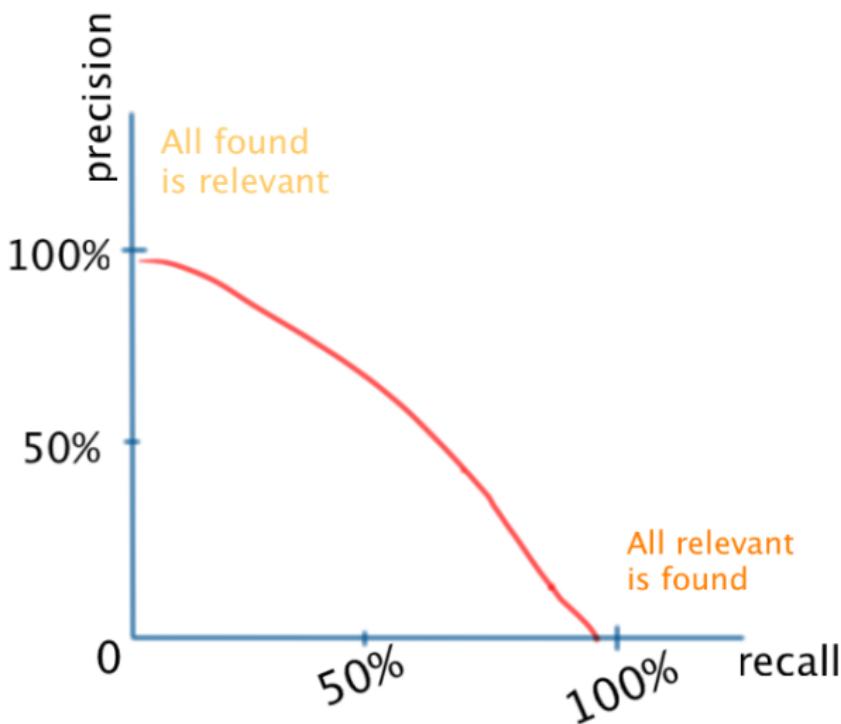
Evaluation

Precision and Recall



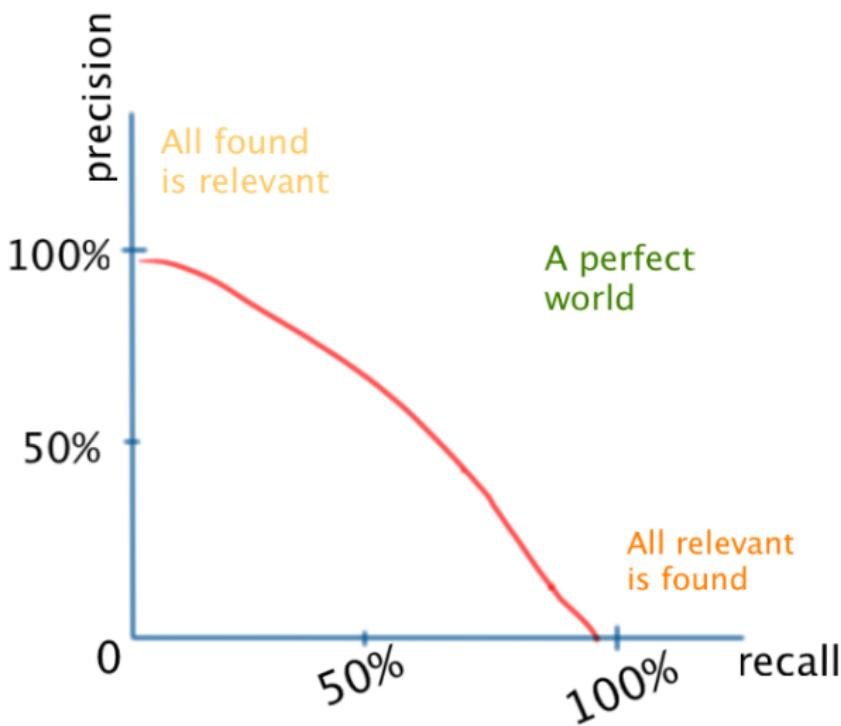
Evaluation

Precision and Recall



Evaluation

Precision and Recall



Evaluation

Precision and Recall

An example:

n	doc #	relevant
1	588	x
2	589	x
3	576	
4	590	x
5	986	
6	592	x
7	984	
8	988	
9	578	
10	985	
11	103	
12	591	
13	772	x
14	990	

Let total # of relevant docs = 6
Check each new recall point:

$R=1/6=0.167; P=1/1=1$

$R=2/6=0.333; P=2/2=1$

$R=3/6=0.5; P=3/4=0.75$

$R=4/6=0.667; P=4/6=0.667$

$R=5/6=0.833; P=5/13=0.38$

Missing one relevant document.
Never reach 100% recall

We suppose we know the number of relevant documents.

Evaluation

Single Value Measures

Often, we'd prefer one single value to express the performance of the IRS.

- Precision over the top n found documents:
 - e.g., $P@5$, $P@10$ (5 or 10 documents have been seen)
 - good precision on the top of the list -> positive user impression
 - web search
- R-Precision:
 - R - the total number of relevant docs for a given query
 - compute precision at the R th position of the ranking
 - e.g., $R = 6$, but 4 relevant in the top 6 => R-Precision = 4/6

n	doc #	relevant
1	588	x
2	589	x
3	576	
4	590	x
5	986	
6	592	x
7	984	
8	988	

$R = \# \text{ of relevant docs} = 6$

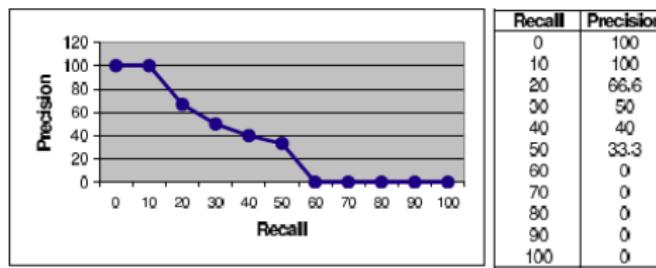
$\text{R-Precision} = 4/6 = 0.67$

Evaluation

Single Value Measures

- **MAP:** mean average precision over the first n documents

- e.g., for 10 documents: $MAP = \frac{P_1+P_2+\dots+P_{10}}{10} = \frac{1+1+0.6+0.5+0.4+0.33+0+0+0+0}{10}$



- **F-measure** (the harmonic mean of precision and recall at the j -th position of the ranking)
 - $F(j) = \frac{2P(j)R(j)}{P(j)+R(j)} \in [0, 1]$
 - high F \Leftarrow both P and R high
 - good compromise between P and R

Evaluation

Accuracy?

	Relevant	Nonrelevant
Retrieved	tp	fp
Not Retrieved	fn	tn

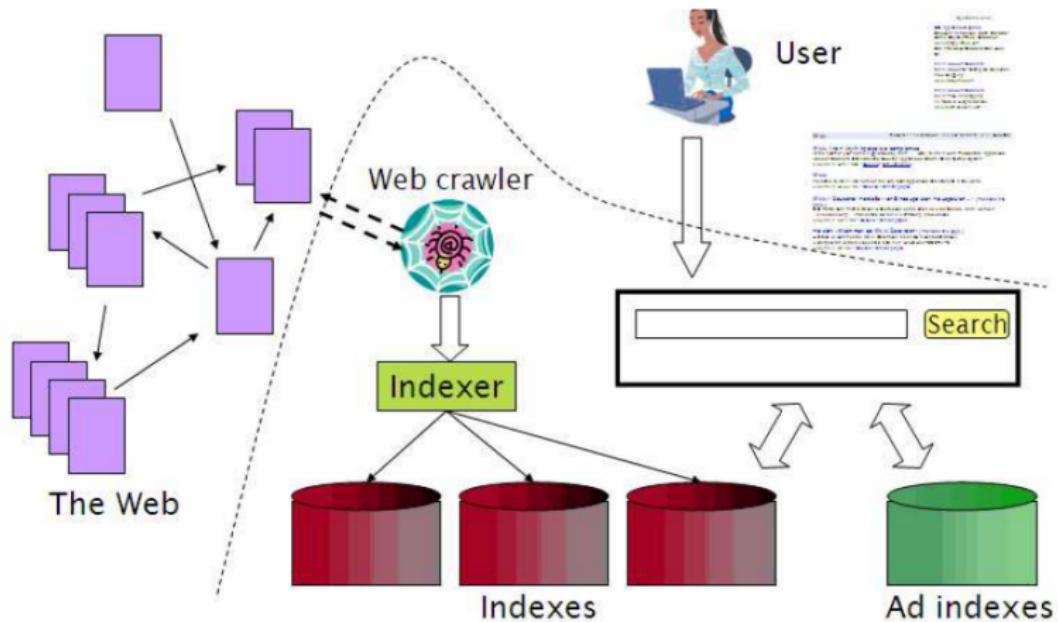
$$Accuracy = \frac{tp+tn}{all}$$

- A measure often used in classification (see following lecture)
- Not appropriate for IR because...
- Data are biased: about 99.9% of the documents are non relevant
- We would like to tolerate error: an IR system is expected to return something!

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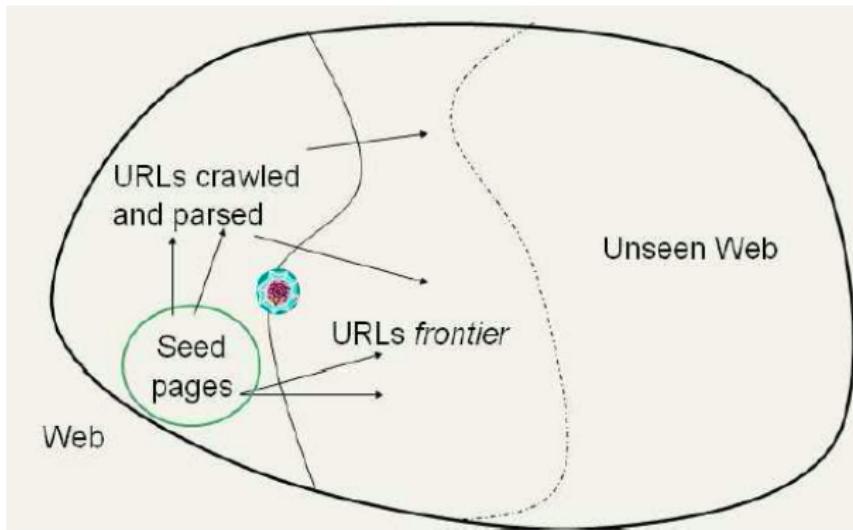
Web Search



From H. Schuetze

Web Search

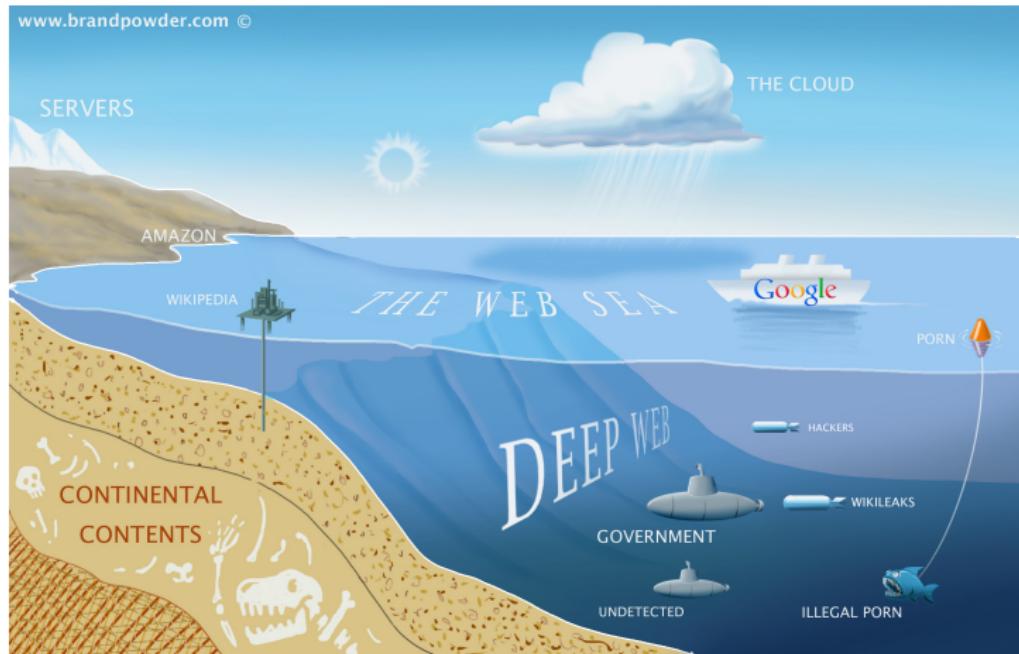
An idea about crawling...



Web Search

The Deep Web?

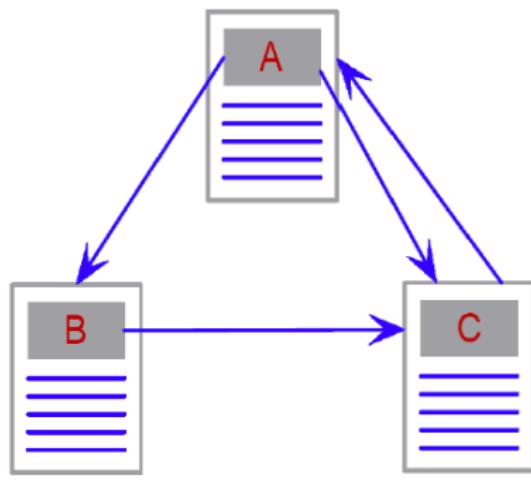
Search engines index about 6% of the entire web content.



Web Search

The nature of the Web

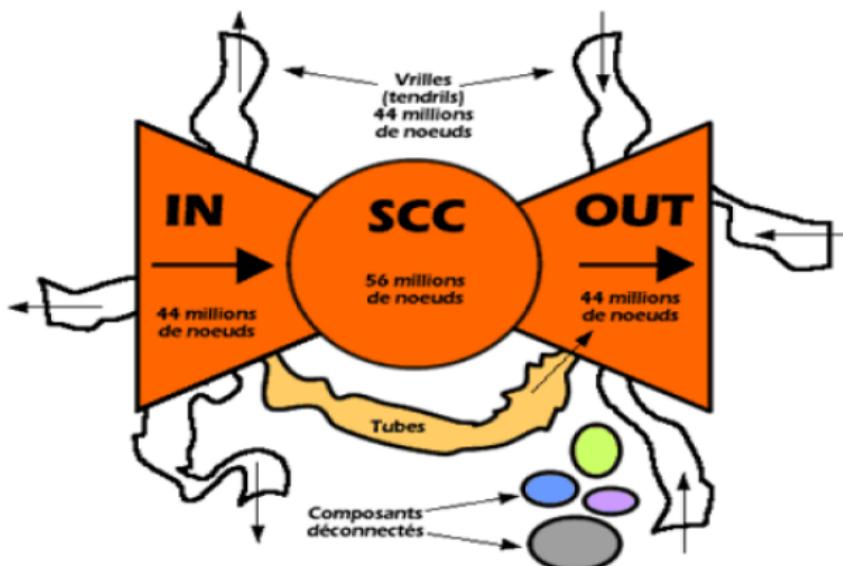
The static web: a graph representation induced by the hyperlinks.



Web Search

The nature of the Web

The Bow-tie model of the web:



Three main page categories: **IN, OUT, SCC** (Strongly Connected Component)
From Broder et al.

Web Search

Link Analysis

- Google's PageRank (Brin and Page, 1998)
- Many different variants of this algorithm

Main idea:

- The Web is an **oriented graph**
- The **links** carry important information
 - A link between two pages indicates a **relevance relation** between them
 - The **text of the link** describes the target page: important for indexing !
...well, not always:
"You can find useful information about New Delhi's economy [here.](#)"

Web Search

The algorithm in a nutshell:

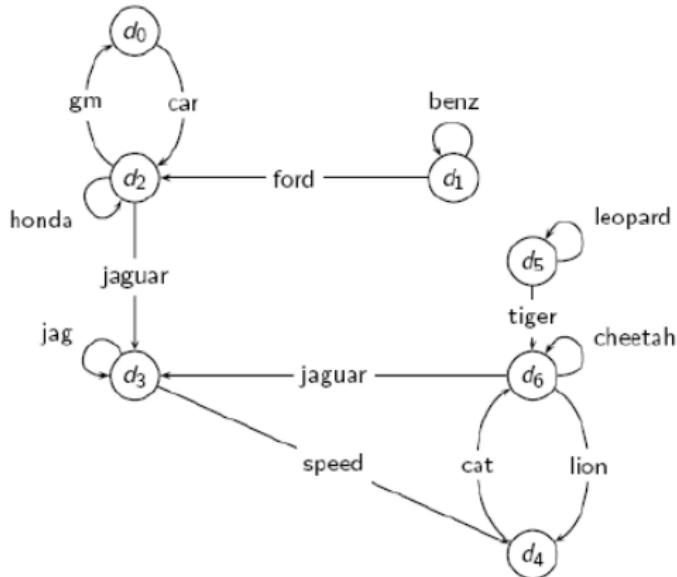
- A random walk through the Web graph (modeled as a Markov chain)
- At each step, the walker leaves a page by following one of its links (with an equal probability)
- If a page has no out-links: jump on to an arbitrary page with a given probably p
- The PageRank is the probability that the walker is at page d , after a given time, t

→ "The likelihood that a person randomly clicking on links will arrive at a certain page, after a time t ."

→ A rough estimate of how important a website is.

Web Search

Example:



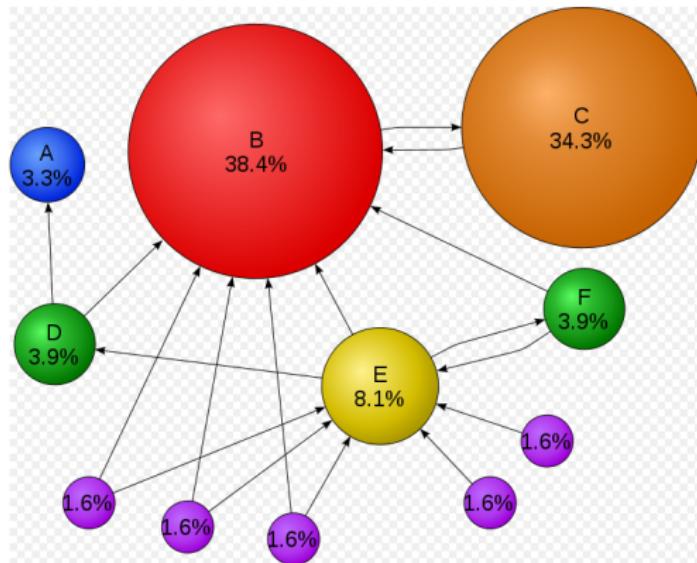
Web Search

Example: the transition matrix.

	d_0	d_1	d_2	d_3	d_4	d_5	d_6
d_0	0.00	0.00	1.00	0.00	0.00	0.00	0.00
d_1	0.00	0.50	0.50	0.00	0.00	0.00	0.00
d_2	0.33	0.00	0.33	0.33	0.00	0.00	0.00
d_3	0.00	0.00	0.00	0.50	0.50	0.00	0.00
d_4	0.00	0.00	0.00	0.00	0.00	0.00	1.00
d_5	0.00	0.00	0.00	0.00	0.00	0.50	0.50
d_6	0.00	0.00	0.00	0.33	0.33	0.00	0.33

Web Search

The importance of a page depends not only on the number of links.



source: Wikipedia

Web Search

So, let's start.

$$1. PR(p) = \sum_{p_i \rightarrow p} 1$$

OK, but if p_i has many out-links, the probability of going to p becomes smaller!

$$2. PR(p) = \sum_{p_i \rightarrow p} \frac{1}{out(p_i)}$$

That's better. But if p_i is a very important page?

$$3. PR(p) = \sum_{p_i \rightarrow p} \frac{PR(p_i)}{out(p_i)}$$

And what if I don't follow the links, but decide to jump to a random page?

$$4. PR(p) = \frac{(1-d)}{N} + d \times \sum_{p_i \rightarrow p} \frac{PR(p_i)}{out(p_i)}$$

Web Search

When a query comes:

- Retrieve the pages that satisfy the query (see standard models)
- Rank the pages by using PageRank
- Return to the user the ranked list of pages

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- ⑥ **Multimedia Information Retrieval**
- ⑦ Using Semantics and the Web of Data

What about images, video, sound...?

Indexing: text, manual

Users are responsible for providing textual information about an image:



bjork, singer, songwriter, Iceland, female, dancer in the dark, ...

- expensive, depends on the user background, contextual, multilinguism

Indexing: text, automatic

The screenshot shows a Google search results page for the query "tiger river spa". The top result is a link to the "Hot Spring Spas" website, which features a large image of a tiger and the text "Tiger River® Spas Beautiful, Strong, Silent". Below this, there is a snippet of text from the website's page about the Tiger River spa, which includes several words highlighted with red circles: "Tiger River", "spa", "is bred", "to", "perfection", "the", "makers", "of", "Hot", "Spring", "spas", "the", "world's", "number", "one", "selling", "brand", "of", "portable", "spas", "The", "raw", "power", "and", "strength", "of", "innovative", "engineering", "combine", "with", "graceful", "lines", "and", "agile", "instrumentation", "capable", "of", "rescuing", "you", "from", "the", "daily", "jungle". Another snippet below describes the spa as being named after tigers, with the word "Tiger" circled again.

Hot Spring Spas
of Santa Cruz & San Jose

Tiger River® Spas
Beautiful, Strong, Silent

Ever Tiger River spa is bred to perfection by the makers of Hot Spring spas, the world's number one selling brand of portable spas. The raw power and strength of innovative engineering combine with graceful lines and agile instrumentation, capable of rescuing you from the daily jungle.

Tiger River® spas are poised in a state of constant readiness, devouring tension and muscle pain with rejuvenating hydromassage. Like the Caspian, Bengal and Sumatran tigers for which they are named, Tiger River spas are the perfect blend of playfulness, power and grace. A Tiger River spa is not just a hot tub; it's an escape from the jungle of everyday life. Immerse yourself in the taming waters of the Caspian, Bengal, or Sumatran models and feel the power and grace that our Tiger River® spas apart from the rest. Discover why our hot tubs have been named for these awe-inspiring animals. Whether you crave a great hydromassage or a relaxing escape, a beautiful, strong, and silent Tiger River® spa provides the hot tub experience you've been searching for.

Tiger Leaping Gorge
482 x 310 - 18k
blogs.booksnall.com

members.got.com

www.torafolia.com

Multimedia IR

If an image is indexed by using textual information,
the query is a set of key words (see previous sections).

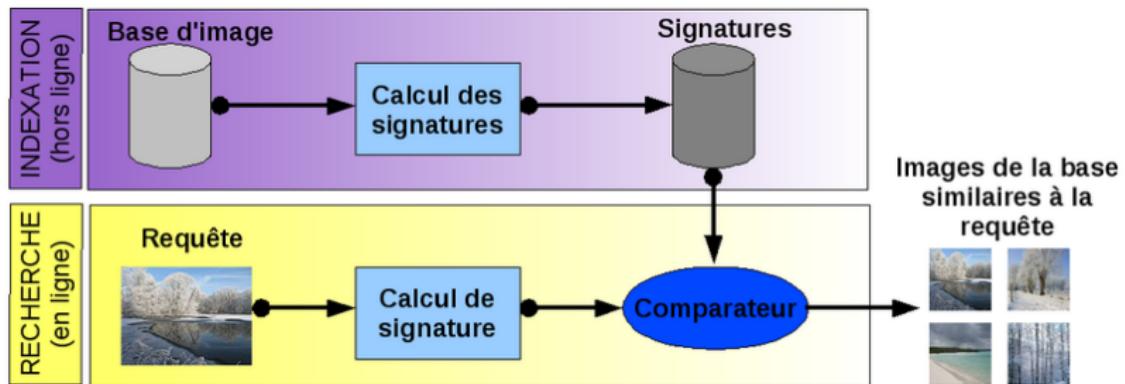
Google

Web **Images** Vidéos Shopping Actualités Plus ▾ Outils de recherche

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Indexing: visual content

- Automatic extraction of numerical descriptors (features) from an image
- Field: content-based image retrieval (CBIR)



Source: Wikipedia

- Open research problem in CBIR: the semantic gap.

Multimedia IR

If an image is indexed by using its content, the query is an image.

The screenshot shows a search interface with a query image of Björk's face. The search term 'bjork debut' is entered in the search bar. The results are categorized under 'Images'.

Environ 563 résultats (0,84 secondes)

Taille de l'image :
950 × 950

Trouver d'autres tailles de l'image :
Toutes les tailles - Petite - Moyennes - Grandes

Hypothèse la plus probable pour cette image : [bjork debut](#)

Debut - Wikipédia
fr.wikipedia.org/wiki/Debut ▾

Debut est le deuxième album studio de la chanteuse islandaise Björk. Il fut commercialisé en juillet 1993 (sous les labels Elektra Records pour les Etats-Unis et ...

Björk - Wikipédia
fr.wikipedia.org/wiki/Björk ▾

Aller à [Début](#) [modifier | modifier le code]. 1992 voit la séparation du groupe, pourtant toujours en plein succès. En 1993, Björk part s'installer à ...

Images similaires - Signaler des images inappropriées

[Rizzys](#)

Debut

Album musical

Debut est le deuxième album studio de la chanteuse islandaise Björk. Il fut commercialisé en juillet 1993. Il s'agit de son premier album en solo depuis son départ du groupe The Sugarcubes. [Wikipedia](#)

Date de sortie : 5 juillet 1993

Artiste : Björk

Labels : One Little Indian Records, Polydor K.K.

Titres

1	Human Behaviour	3:33
2	Crying	4:52
3	Venus As A Boy	4:43
4	There's More to Life Than This	3:18
5	Like Someone in Love	4:33

Recherches associées

Homogenic 1997, Björk	Vespertine 2001, Björk	Medúlla 2004, Björk	Post 1995, Björk	Volta 2007, Björk

Often a hybrid search...

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The Web of Data

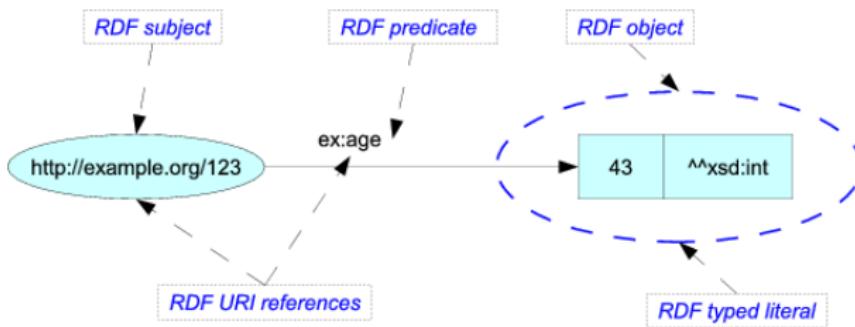
The web of data, or the semantic web - a new vision of the web.

- From a web of documents -> to a web of data
- Not about how documents are connected, but about how things are connected
- A global network of information
- Discover connected and relevant pieces of information that are not found on one single page, nor on pages linked by hyperlinks
- Using semantics and strict rules of publishing data: we will come back to that in a further lecture.

The Web of Data

The web of data, or linked open data - a new vision of the web.

Publish data in the form of a structured dataset using the **RDF formalism**.



IR: more like querying a database by using an adapted **query language (SPARQL)**.

The Web of Data

Environ 4 430 000 000 résultats (0,24 secondes)

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[OK](#) [En savoir plus](#)

Conseil : [Recherchez des résultats uniquement en français](#). Vous pouvez indiquer votre langue de recherche sur la page [Préférences](#).

[The National](#)

[americanmary.com/](#) - Traduire cette page

Join Our Mailing List. **The National** - Trouble Will Find Me. New Album Out Now.

iTunes / Amazon / Vinyl. NEWS. We'd like to hear your cover of "I Need My Girl.

Tour Archive - Trouble Will Find Me - Think You Can Wait / Exile Ylifly

[The National \(groupe\) - Wikipédia](#)

[fr.wikipedia.org/wiki/The_National_\(groupe\)](#) -

The National en concert à la Brooklyn Academy of Music en 2010. Informations générales. Pays d'origine, Cincinnati, Drapeau des États-Unis États-Unis.

Histoire du groupe - Membres du groupe - Discographie - Bandes originales

[The National - "Demons" - YouTube](#)



www.youtube.com/watch?v=N527oBKIPMc -

8 avr. 2013 - Ajouté par thenationalofficial

From the album Trouble Will Find Me, out now:
<http://bit.ly/1ONQPA1> Illustration and video by Azar Kazimir ...

[Latest and breaking news | thenational.ae - The National](#)

[www.thenational.ae/](#) - Traduire cette page

Get the latest news, business, sport, lifestyle, arts, culture and more from **The National**, the leading English-language voice in the Middle East - [thenational.ae](#).

[Pourquoi je déteste The National | Slate](#)

[www.slate.fr/story/75063/pourquoi-je-deteste-the-national](#) -

15 juil. 2013 - **The National** me donne l'impression que le rock --comme une grande



[Plus d'images](#)

The National

Compositeur

The National est un groupe américain de rock indépendant formé à Cincinnati en 1999 et basé à Brooklyn. Il se compose de l'auteur-compositeur-interprète Matt Berninger et des quatre frères Dessner, Aaron et Bryce, et Devendorf, Bryan et Scott. [Wikipedia](#)

Membres : Matt Berninger, Bryce Dessner, Aaron Dessner, Bryan Devendorf, Scott Devendorf

Labels : Beggars Banquet Records, 4AD, Brassland Records

Origine : Brooklyn, État de New York, États-Unis, Cincinnati, Ohio, États-Unis

Sélections : Grammy Award du meilleur album de musique alternative, plus...

Événements à venir

4 févr.
mar. **The National**
Auckland

6 févr.
jeu. **The National**
Torrensville

7 févr.
ven. **The National**
Sydney

Semantics: **The National** is a band and they give a concert on 4th February in Auckland.

Retrieval vs. mining?

IR and Data Mining

Information retrieval vs. data mining

- IR is about finding what is already there: as fast as possible
- DM is about finding something new in your data that was not known before: as new as possible

Combine both

- group together the documents with respect to their content (see following lecture on clustering and classification)
- disambiguate the different "meanings" of a query and present the results in categories to the user
- diversify
- user profiling and recommendation: find patterns in user search
- query expansion and reformulation
- ...

Sources and further reading

This course uses references from

- a course by Céline Hudelot given at Ecole Centrale Paris. This is Céline's homepage:
<http://perso.ecp.fr/hudelotc/>
- a course by R. Baeza-Yates and B. Ribeiro-Neto. Can be found here:
<http://www.mir2ed.org>

Here are two very useful books:

- C. Manning, P. Raghavan, H. Schuetze. Introduction to Information Retrieval, Cambridge University Press, 2008.
Available online here: <http://nlp.stanford.edu/IR-book/information-retrieval-book.html>
- R. Baeza-Yates, B. Ribeiro-Neto. Modern Information Retrieval. Addison Wesley

Questions?...