VK Multimedia Information Systems

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Information Retrieval Basics: Agenda

- Information Retrieval History
- Information Retrieval & Data Retrieval
- Searching & Browsing
- Information Retrieval Models

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Information Retrieval History

Currently there are no museums for IR

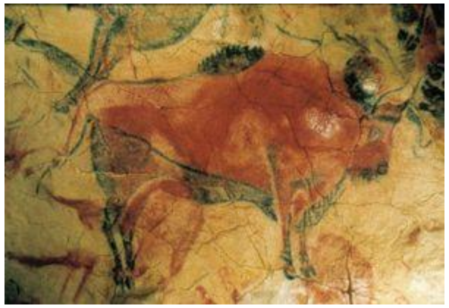
IR is the process of **searching** through a **document collection** based on a particular **information need.**

IR Key Concepts

- Searching
  - Indexing, Ranking
- Document Collection
  - Textual, Visual, Auditive
- Particular Needs
  - Query, User based

A History of Libraries

Libraries are perfect examples for document collections.



- Wall paintings in caves
  - e.g. Altamira, ~ 18,500 years old
- Writing in clay, stone, bones
  - e.g. Mesopotamian cuneiforms, ~ 4.000 BC
  - e.g. Chinese tortoise-shell carvings, ~ 6.000 BC
  - e.g. Hieroglyphic inscriptions, Narmer Palette ~ 3.200 BC

A History of Libraries (ctd.)

- Papyrus
  - Specific plant (subtropical)
  - Organized in rolls, e.g. in Alexandria
- Parchment
  - Independence from papyrus
  - Sewed together in books
- Paper
  - Invented in China (bones and bamboo too heavy, silk too expensive)
  - Invention spread -> in 1120 first paper mill in Europe

A History of Libraries (ctd.)

- Gutenberg’s printing press (1454)
  - Inexpensive reproduction
  - e.g. “Gutenberg Bible”
- Organization & Storage
  - Dewey Decimal System (DDC, 1872)
  - Card Catalog (early 1900s)
  - Microfilm (1930s)
  - MARC (Machine Readable Cataloging, 1960s)
  - Digital computers (1940s+)

Library & Archives today

- Partially converted to electronic catalogues
  - From a certain time point on (1992 - ...)
  - Often based on proprietary systems
  - Digitization happens slowly
  - No full text search available
  - Problems with preservation
    - Storage devices & formats

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History of Searching

- Browsing
  - Like “finding information yourself”
- Catalogs
  - Organized in taxonomies, keywords, etc.
- Content Based Searching
  - `SELECT * FROM books WHERE title='%Search%'`
- Information Retrieval
  - ranking, models, weighting
  - link analysis, LSA, ...

History of IR

- Starts with development of computers
- Term “Information Retrieval” coined by Mooers in 1950
  - Mooers, C. (March 1950). "The theory of digital handling of non-numerical information and its implications to machine economics". *Proceedings of the meeting of the Association for Computing Machinery at Rutgers University*.

- Two main periods (Spark Jones u. Willett)
  - 1955 – 1975: academic research
    - models and basics
    - main topics: search & indexing
  - 1975 – ... : commercial applications
    - improvement of basic methods

A Challenge: The World Wide Web

- First actual implementation of **Hypertext**
  - Interconnected documents
  - Linked and referenced
- World Wide Web (1989, T. Berners-Lee)
  - Unidirectional links (target is not aware)
  - Links are not typed
  - Simple document format & communication protocol (HTML & HTTP)
  - Distributed and not controlled

Some IR History Milestones

- Book "Automatic Information Organization and Retrieval", *Gerard Salton* (1968)
  - Vector space model
- Paper "A statistical interpretation of term specificity and its application in retrieval", Karen Sparck Jones (1972)
  - IDF weighting
  - http://www.soi.city.ac.uk/~ser/idf.html
- Book "Information Retrieval" of *C.J. Rijsbergen* (1975)
  - Probabilistic model
  - http://www.dcs.gla.ac.uk/Keith/Preface.html

Some IR History Milestones

- Paper “Indexing by Latent Semantic Analysis”, S. Deerwester, Susan Dumais, G. W. Furnas, T. K. Landauer, R. Harshman (1990).
  - Latent Semantic Indexing
- Paper “Some simple effective approximations to the 2-Poisson model for probabilistic weighted retrieval” Robertsen & Walker (1994)
  - BM25 weighting scheme
- Paper “The Anatomy of a Large-Scale Hypertextual Web Search Engine”, *Sergey Brin & Larry Page* (1998)
  - World wide web retrieval

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- Searching & Browsing
- Information Retrieval Models

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Organizational: References

- in the Library
  - *Modern Information Retrieval*, Ricardo Baeza-Yates & Berthier Ribeiro-Neto, Addison Wesley
  - *Google's Pagerank and Beyond: The Science of Search Engine Rankings*, Amy N. Langville & Carl D. Meyer, University Presses of CA
  - *Readings in Information Retrieval*, Karen Sparck Jones, Peter Willett, Morgan Kaufmann

Organizational: References

- On the WWW
  - *Skriptum Information Retrieval*, Norbert Fuhr, Lecture Notes on Information Retrieval - Univ. Dortmund, 1996. Updated in 2002
  - *Information Retrieval 2nd Edt.*, C.J. Rijsbergen, Butterworth, London 1979
- Through me:
  - *Lectures on Information Retrieval: Third European Summer-School, Essir 2000 Varenna, Italy, Revised Lectures*, Maristella Agosti, Fabio Crestani & Gabriela Pasi (eds.), Lecture Notes in Computer Science, Springer 2000

Information Retrieval & Data Retrieval

Information Retrieval	Data Retrieval
Information Level	Data Level
Search Engine	Data Base
Teoma / Google	Oracle / MySQL

Information Retrieval & Data Retrieval

Information Retrieval	**Data Retrieval**
Content Based Search	Search for Patterns and String
Query ambigous	Query formal & unambigous
Results ranked by relevance	Results not ranked
Error tolerant	Not error tolerant
Multiple iterations	Clearly defined result set
Examples	*Examples*
Search for synonyms	Search for patterns
Bag of Words	SQL Statement

- Retrieval is nearly always a combination of both.

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Information Retrieval Basics: Searching

A **user** has an **information need**, which needs to be **satisfied**.

- Two different approaches:
  - Browsing
  - Searching

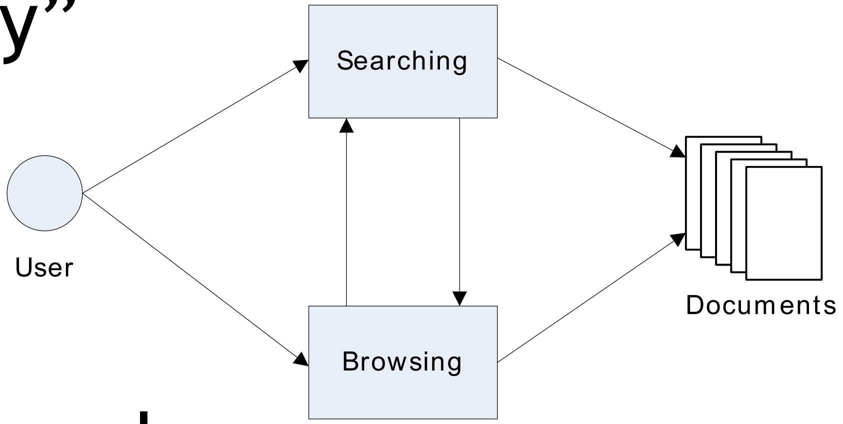
Searching & Browsing

Searching

- Explicit information need
- Definition through “query”
- Result lists
- e.g. Google

Browsing

- Not necessarily explicit need
- Navigation through repositories



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Browsing

- Flat Browsing
  - User navigates through set of documents
  - No implied ordering, explicit ordering possible
  - Examples: One single directory, one single file
- Structure Guided Browsing
  - An explicit structure is available for navigation
  - Mostly hierarchical (file directories)
  - Can be generic digraph (WWW)
  - Examples: File systems, World Wide Web

Searching

- Query defines “Information Need”

- Ad Hoc Searching
  - Search when you need it
  - Query is created to fit the need
- Information Filtering
  - Make sets of documents smaller
  - Query is filter criterion
- Information Push
  - Same as filtering, delivery is different

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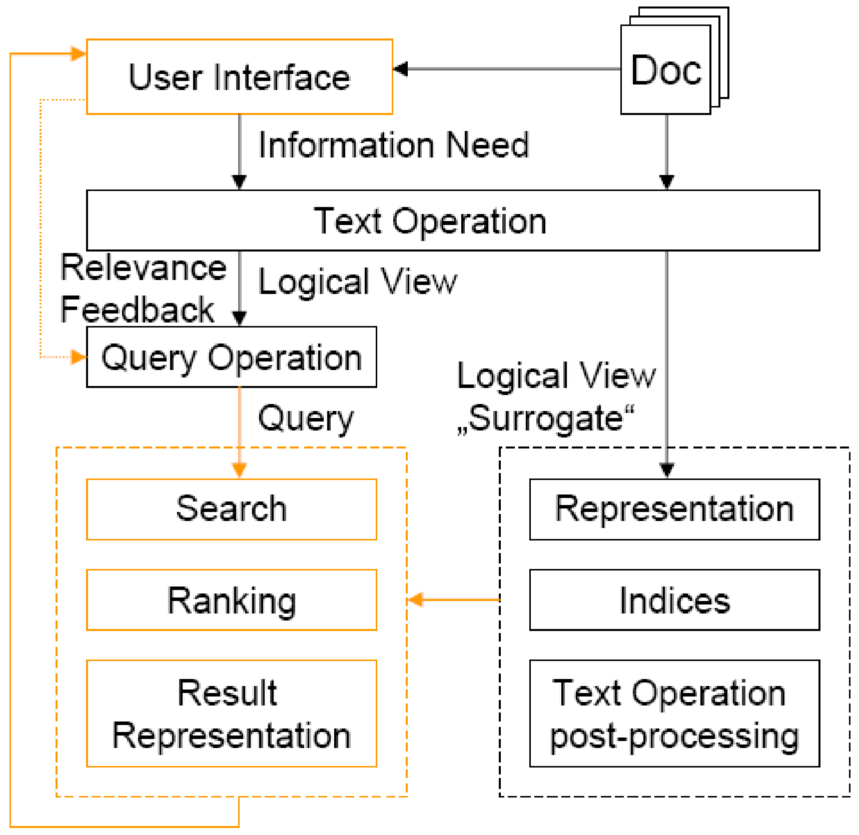
Information Retrieval System Architecture

Aspects

- Query & languages
- IR models
- Documents
- Internal representation
- Pre- and post-processing
- Relevance feedback
- HCI



Information Retrieval Models

- Boolean Model
  - Set theory & Boolean algebra
- Vector Model
  - Non binary weights on dimensions
  - Partial match
- Probabilistic Model
  - Modeling IR in a probabilistic framework

Formal Definition of Models

An information retrieval model is a quadruple [D, Q, F, R(q_i, d_j)]

- *D* is a set of logical views (or representations) for the **documents** in the collection.
- *Q* is a set of logical views (or representations) for the user needs or **queries**.
- F is a **framework** for modeling document representations, queries and their relationship.
- *R*(q_i, d_j) is a **ranking function** which associates a real number with a query q_i of *Q* and a document d_j of *D*.

Definitions

in Context of Text Retrieval

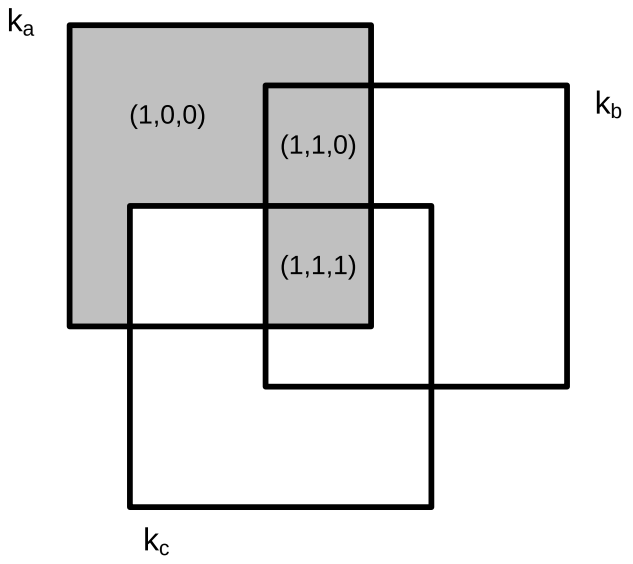
- **index term** – word of a document expressing (part of) document semantics
- **weight $w_{i,j}$** – quantifies the importance of index term t_i for document d_j
- index term vector for document d_j (having t different terms in all documents):

$$\overrightarrow{d_j} = (w_{1,j}, w_{2,j}, \ldots, w_{t,j})$$

Boolean Model

- Based on set theory and Boolean algebra
  - Set of index terms
  - Query is Boolean expression
- Intuitive concept:
  - Wide usage in bibliographic system
  - Easy implementation and simple formalisms
- Drawbacks:
  - Binary decision components (true/false)
  - No relevance scale (relevant or not)

Boolean Model: Example



$$q = k_a \wedge (k_b \vee \neg k_c)$$

Boolean Model: DNF

$$q = k_a \wedge (k_b \vee \neg k_c) \;\ldots\; \vec{q}_{dnf} = (1,1,1) \vee (1,1,0) \vee (1,0,0)$$

- Express queries in *disjunctive normal form* (disjunction of conjunctive components)
- Each of the components is a binary weighted vector associated with (k_a, k_b, k_c)
- Weights $w_{i,j} \in \{0,1\}$

Boolean Model: Ranking function

$$sim(d_j, q) = \begin{cases} 1 & \text{if } \exists \vec{q}_{cc} \,\middle|\, (\vec{q}_{cc} \in \vec{q}_{dnf}) \wedge (\forall_{k_i}, g_i(\vec{d}_j) = g_i(\vec{q}_{cc})) \\ 0 & \text{otherwise} \end{cases}$$

- similarity is one if one of the conjunctive components in the query is exactly the same as the document term vector.

Boolean Model

- Advantages
  - Clean formalisms
  - Simplicity
- Disadvantages
  - Might lead to too few / many results
  - No notion of **partial match**
  - Sequential ordering of terms not taken into account.

Vector Model

- Integrates the notion of partial match
- Non-binary weights (terms & queries)
- Degree of similarity computed

$$\vec{d}_j = (w_{1,j}, w_{2,j}, \ldots, w_{t,j})$$

$$\vec{q} = (w_{1,q}, w_{2,q}, \ldots, w_{t,q})$$

Vector model: Similarity

$$sim(d_j, q) = \frac{\vec{d}_j \bullet \vec{q}}{\left|\vec{d}_j\right| \times \left|\vec{q}\right|} = \frac{\sum_{i=1}^{t} w_{i,j} \cdot w_{i,q}}{\sqrt{\sum_{i=1}^{t} w_{i,j}^2} \cdot \sqrt{\sum_{i=1}^{t} w_{i,q}^2}}$$

Vector Model: Example

$$\vec{d} = (0.3, 0.1, 0, 0.1, 1)$$

$$\vec{q} = (1, 0, 0, 0.5, 0)$$

$$sim(\vec{d}, \vec{q}) = \frac{1 \cdot 0.3 + 0.1 \cdot 0.5}{\sqrt{0.3^2 + 0.1^2 + 0.1^2 + 1^2} \cdot \sqrt{1 + 0.5^2}} \approx \frac{0.35}{2.24} \approx 0.17$$

Another Example:

- Document & Query:
  - D = “The quick brown fox jumps over the lazy dog”
  - Q = “brown lazy fox”

$$sim(d_j, q) = \frac{\vec{d}_j \bullet \vec{q}}{\left|\vec{d}_j\right| \times \left|\vec{q}\right|} = \frac{\sum_{i=1}^{t} w_{i,j} \cdot w_{i,q}}{\sqrt{\sum_{i=1}^{t} w_{i,j}^2} \cdot \sqrt{\sum_{i=1}^{t} w_{i,q}^2}}$$

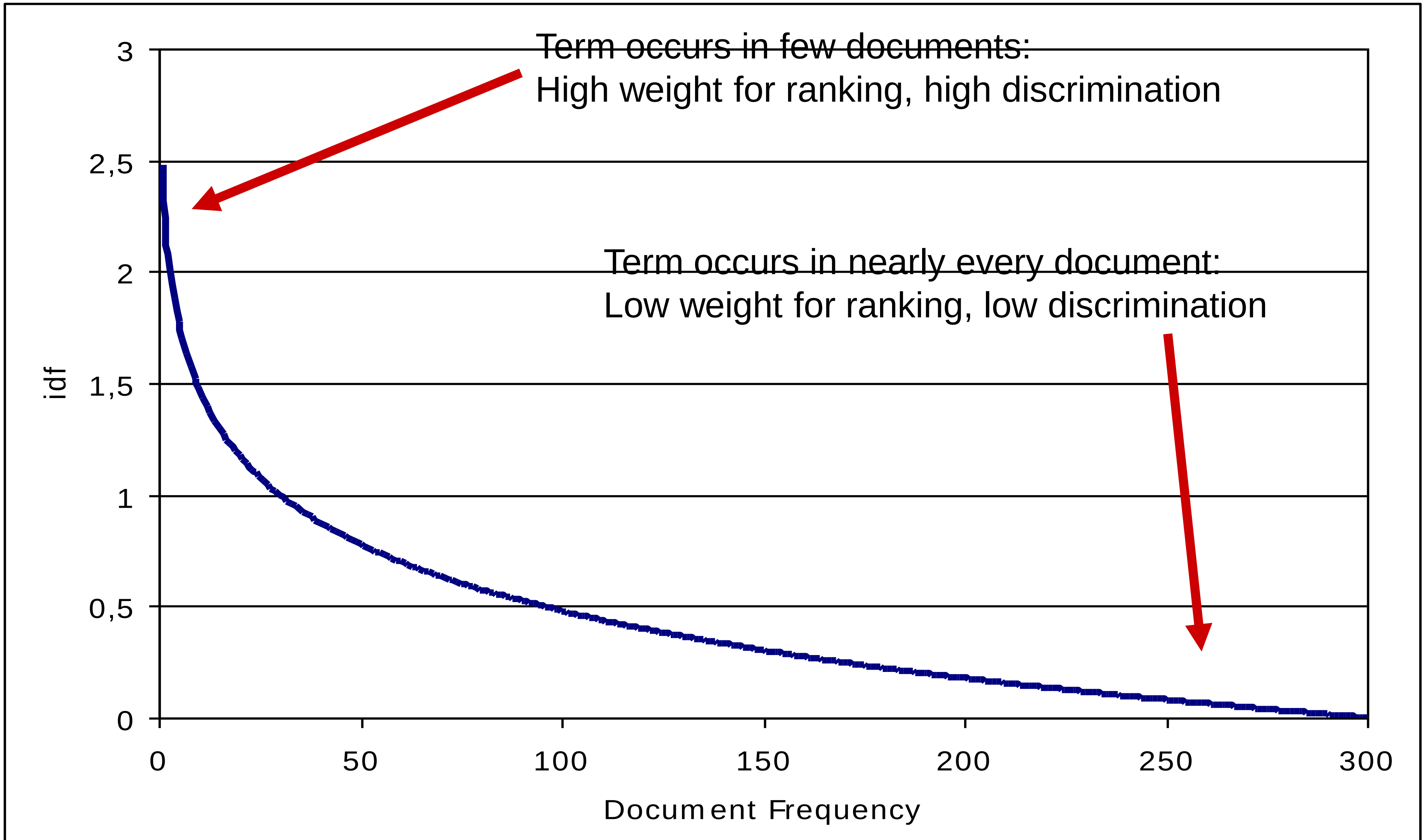
- Results:
  - $(1,1,1,1,1,1,1,2)^t * (1,1,1,0,0,0,0,0)^t = 3$
  - sqrt(11) * sqrt(3) = sqrt(3*11) = sqrt(33)
  - Similarity = 3 / sqrt(33) ~= 0.5222

Term weighting: TF*IDF

Term weighting increases retrieval performance

- Term frequency
  - How often does a term occur in a document?
  - Most intuitive approach
- Inverse Document Frequency
  - What is the information content of a term for a document collection?
  - Compare to *Information Theory* of Shannon

Example: IDF
300 documents corpus



Definitions: Normalized Term Frequency

$$f_{i,j} = \frac{freq_{i,j}}{\max_l(freq_{l,j})}$$ ... normalized term frequency

$freq_{i,j}$ ... raw term frequency of term i in document j

- Maximum is computed over all terms in a document
- Terms which are not present in a document have a raw frequency of *0*

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Definitions: Inverse Document Frequency

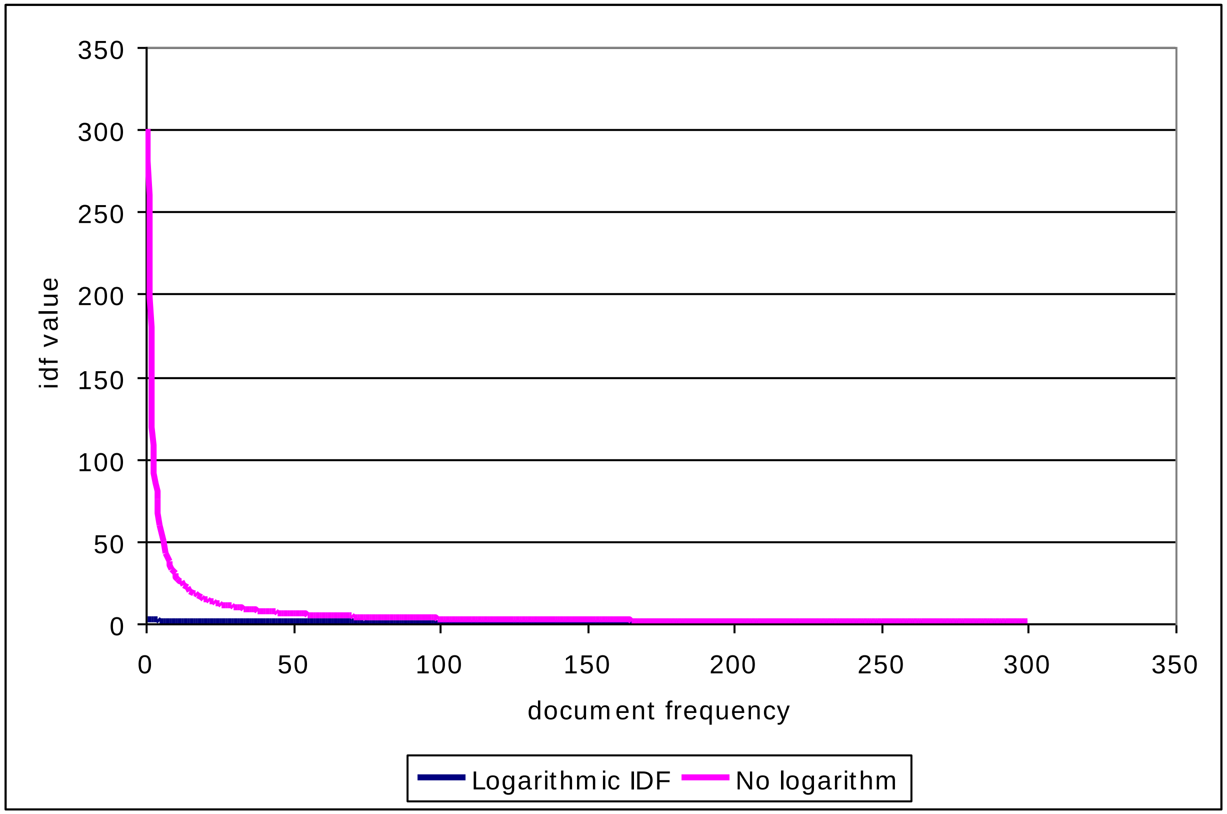
$idf_i = \log \frac{N}{n_i}$ ... inverse document frequency for term i

N ... number of documents in the corpus

n_i ... number of document in the corpus which contain term i

- Note that idf_i is independent from the document.
- Note that the whole corpus has to be taken into account.

Why log(...) in IDF?



TF*IDF

- TF*IDF is a very prominent weighting scheme
  - Works fine, much better than TF or Boolean
  - Quite easy to implement

$$w_{i,j} = f_{i,j} \cdot \log \frac{N}{n_i}$$

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Weighting of query terms

$$w_{i,q} = (0.5 + \frac{0.5 \cdot f_{i,q}}{\max_l(f_{l,q})}) \cdot \log \frac{N}{n_i}$$

- Also using IDF of the corpus
- But TF is normalized differently
  - TF > 0.5
- Note: the query is not part of the corpus!

Vector Model

- Advantages
  - Weighting schemes improve **retrieval performance**
  - Partial matching allows retrieving documents that **approximate query** conditions
  - Cosine coefficient allows **ranked list** output
- Disadvantages
  - Term are assumed to be mutually independent

Simple example (i)

- Scenario
  - Given a **document corpus on birds**: nearly each document (say 99%) contains the word bird
  - someone is searching for a document about sparrow nest construction with a query **“sparrow bird nest construction”**
  - Exactly the document which would satisfy the user needs **does not have the word “bird”** in it.

Simple example (ii)

- TF*IDF weighting
  - knows upon the low discrimative power of the term bird
  - The weight of this term is near to zero
  - This term has virtually no influence on the result list.

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Exercise 01

- Given a document collection …
- Find the results to a query …
  - Employing the Boolean model
  - Employing the vector model (with TF*IDF)

- Some hints:
  - Excel:
    - Sheet on homepage
    - Use functions “Summenprodukt” & “Quadratesumme”

Exercise 01

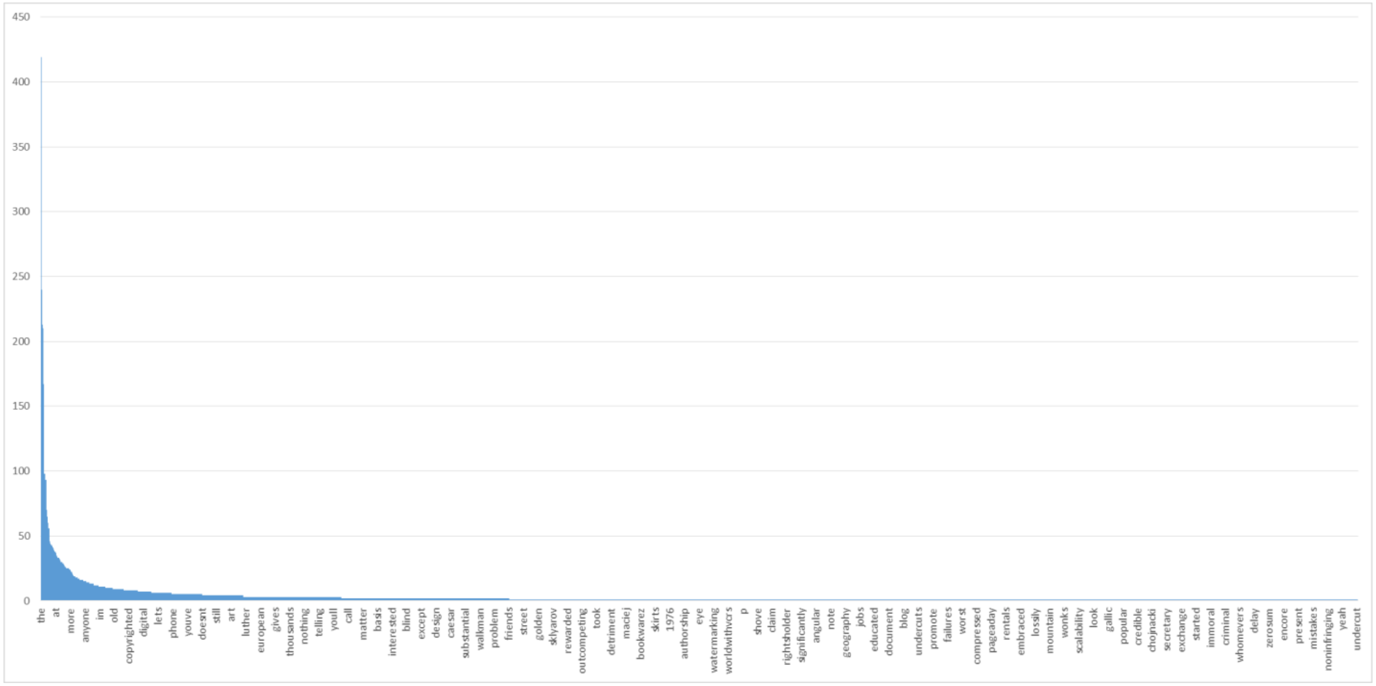
- Document collection (6 documents)
  - spatz, amsel, vogel, drossel, fink, falke, flug
  - spatz, vogel, flug, nest, amsel, amsel, amsel
  - kuckuck, nest, nest, ei, ei, ei, flug, amsel, amsel, vogel
  - amsel, elster, elster, drossel, vogel, ei
  - falke, katze, nest, nest, flug, vogel
  - spatz, spatz, konstruktion, nest, ei
- Queries:
  - spatz, vogel, nest, konstruktion
  - amsel, ei, nest

Exercise 01

	d1	d2	d3	d4	d6	d6	idf
amsel	1	3	2	1			
drossel	1			1			
ei			3	1		1	
elster				2			
falke	1				1		
fink	1						
flug	1	1	1		1		
katze					1		
konstruktion						1	
kuckuck			1				
nest		1	2		2	1	
spatz	1	1				2	
vogel	1	1	1	1	1		

Exercise 02

- Create a **term** vector of a text file
  - with a language of your choice, raw frequency
- Create a graph



Exercise 02 - Ideas ...

- Make sure you remove ^[A-Za-z0-9]
- Make sure to normalize the case
  - ie. by using lower case
- Print
  - `term + „\t“ + value`
- Import output to Excel

Don‘t forget ..

- To send me the results of Exercise 01
- and the graph from Exercise 02

Thanks …

for your attention!

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