

Introduction to Ad-hoc Retrieval

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INLS 509: Information Retrieval

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Ad-hoc Retrieval

- Text-based retrieval
- Given a **query** and a **corpus**, find the **relevant** items
 - ▶ **query**: textual description of information need
 - ▶ **corpus**: a collection of textual documents
 - ▶ **relevance**: satisfaction of the user's information need
- “Ad-hoc” because the number of possible queries is (in theory) infinite.



Examples web search

evo screen capture



► [How to screen capture on evo? - PPCGeeks](#) 🔍

[forum.ppcgeeks.com](#) > ... > [Android HTC Devices](#) > [HTC Evo 4G](#) - [Cached](#)

Jul 6, 2010 – Is there any app for that ? Sent from my PC36100 using Tapatalk.

[Is it possible to screen capture before rooting?](#) - Jul 8, 2011

[Print Screen / Screen capture](#) - Sep 12, 2010

[Print Screen / Screen capture - Page 2](#) - Jun 21, 2010

[More results from forum.ppcgeeks.com »](#)

[How to take screenshots on the HTC EVO 4G - Know Your Cell](#) 🔍

[www.knowyourcell.com/...evo.../evo.../how_to_take_screenshots_o...](#) - [Cached](#)

Apr 15, 2010 – On the HTC **EVO 4G**: HTC Desire screen shot. Press the Home icon, ... Click on the Device menu and select **Screen Capture** or use the CTRL-S key ...

[HTC Evo 4G Apps](#) 🔍

[www.evo4gforum.net](#) > [HTC Evo Media and Miscellaneous](#) - [Cached](#)

HTC **Evo 4G** Apps - Talk about HTC **Evo 4G** Apps here. ... Advanced search · Scratch-Proof your HTC **Evo 4G** · Best Screen Protector for HTC **Evo 4G** · Good Price on HTC **Evo 4G** ... **Screen Capture** (updated 9/27/10) « 1 2

[Android Screenshots: No Root Required with EVO > AndroidGuys](#) 🔍

[www.androidguys.com/2010/05/.../android-screenshots-root-require...](#) - [Cached](#)

May 24, 2010 – We tested this on a stock HTC **EVO 4G** distributed at Google I/O. Let us know in the comments if other **screen capture** apps work on your ...

[How to take screenshots on the HTC EVO 4G](#) 🔍

[www.goodandevo.net/.../how-to-take-screenshots-on-the-htc-evo-4...](#) - [Cached](#)

May 24, 2010 – **Evo-ss** In general, there are two ways to take screenshots on an Android phone: 1) root it and install a **screen capture** app and 2) connect to ...

[Screen Capture/Print Screen App for EVO 2.2 - Android Forums](#) 🔍

[androidforums.com](#) > ... > [HTC EVO 4G](#) > [EVO 4G - Tips and Tricks](#) - [Cached](#)

3 posts - 3 authors - Last post: Aug 11, 2010

I've read several post on **screen capture**, most of which seem to be for advanced users and also risk bricking your phone. Is there a screen ...

Examples scientific search

PubMed

☐ [Metabolic and behavioural effects of sucrose and **fructose**/glucose drinks in the rat.](#)

1. Sheludiakova A, Rooney K, Boakes RA.
Eur J Nutr. 2011 Jul 29. [Epub ahead of print]
PMID: 21800086 [PubMed - as supplied by publisher]
[Related citations](#)

☐ [The impact of **fructose** on renal function and blood pressure.](#)

2. Kretowicz M, Johnson RJ, Ishimoto T, Nakagawa T, Manitius J.
Int J Nephrol. 2011;2011:315879. Epub 2011 Jul 17.
PMID: 21792388 [PubMed - in process] **Free PMC Article**
[Free full text](#) [Related citations](#)

☐ [The role of salt in the pathogenesis of **fructose**-induced hypertension.](#)

3. Soleimani M, Alborzi P.
Int J Nephrol. 2011;2011:392708. Epub 2011 Jul 18.
PMID: 21789281 [PubMed - in process] **Free PMC Article**
[Free full text](#) [Related citations](#)

☐ [Survey of American food trends and the growing **obesity** epidemic.](#)

4. Shao Q, Chin KV.
Nutr Res Pract. 2011 Jun;5(3):253-9. Epub 2011 Jun 21.
PMID: 21779530 [PubMed - in process] **Free PMC Article**
[Free full text](#) [Related citations](#)

☐ [Obesity and energy balance: is the tail wagging the dog?](#)

5. Wells JC, Siervo M.
Eur J Clin Nutr. 2011 Jul 20. doi: 10.1038/ejcn.2011.132. [Epub ahead of print]
PMID: 21772313 [PubMed - as supplied by publisher]
[Related citations](#)




Examples

discussion forum search

Q thunderbird installation

Search: Keyword(s): thunderbird, installation

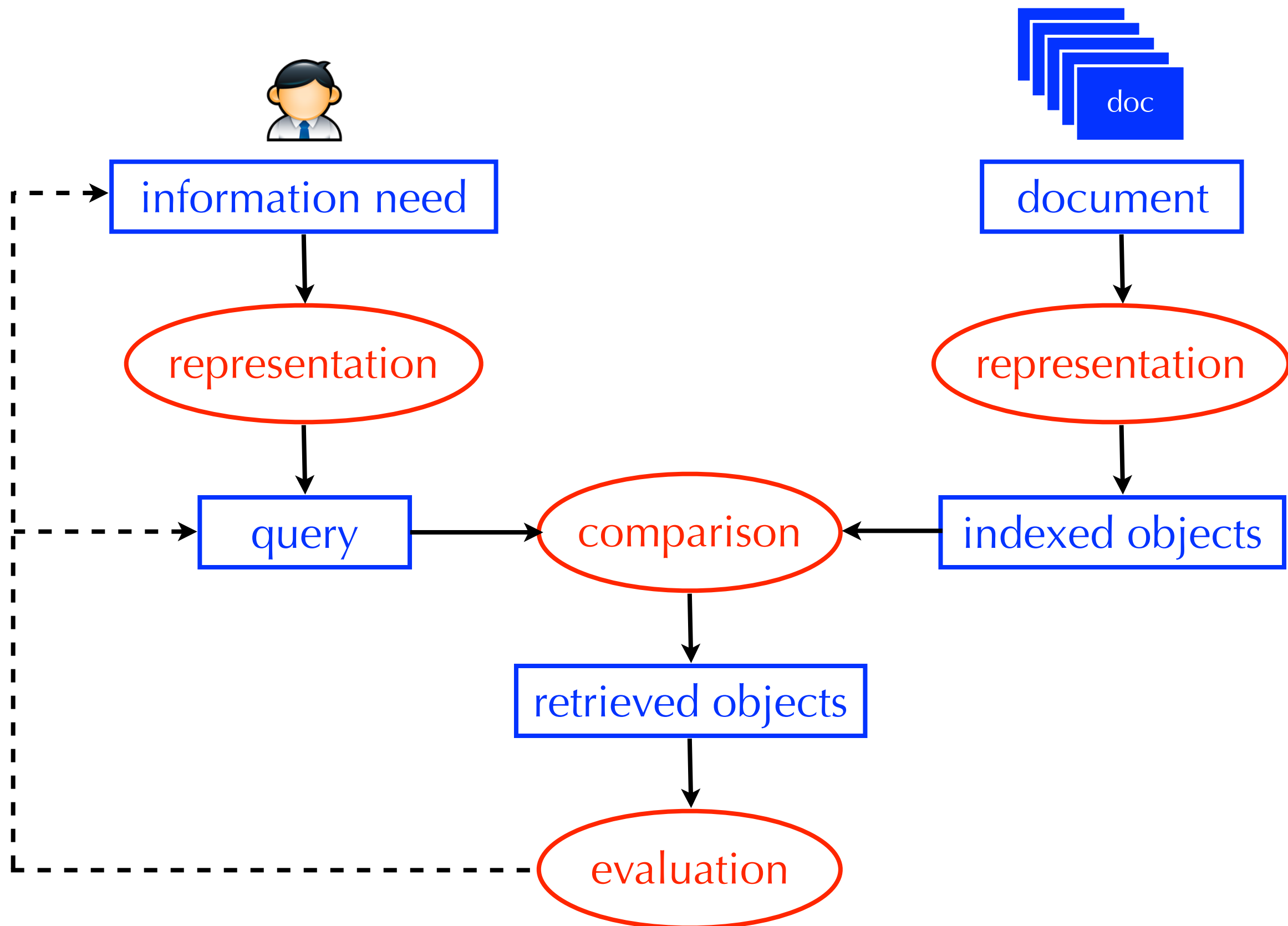
Showing results 1 to 25 of 38
 Search took **0.02** seconds.

	Thread / Thread Starter	Last Post	Replies	Views	Forum
	Pre-Installed Mac Applications (1 2) 'r i S e n	Jul 18, 2011 02:21 AM by RasmusM >	34	1,953	Mac Applications and Mac App Store
	Translucent mail notify BLOND37	Jun 12, 2011 11:45 PM by jive turkey >	8	277	Mac Applications and Mac App Store
	How do I move Thunderbird e-mail from PC to Mac donhnick	Oct 12, 2010 08:41 AM by tommcdonald >	7	35,011	Mac Applications and Mac App Store
	Re-installing 10.6 while preserving user data? Bunker	Feb 28, 2010 10:45 AM by TonyK >	5	708	Mac OS X
	New to MAC - Dissappointed - text size (1 2 3 4 5 6 ... Last Page) MariekeFJ	Jan 19, 2010 12:14 PM by Don Crosswhite >	157	10,115	Mac Basics and Help
	Anyone have to "switch back" due to \$\$? (1 2 3) Schtibbie	Oct 20, 2009 09:30 PM by Kat King123 >	52	2,688	MacBook
	The Saga of Switching ready2switch	May 21, 2009 04:24 PM by Chris.L >	4	493	Mac Basics and Help
	Apple Mail vs Entourage DJAKO	May 8, 2009 06:30 PM by Benquitar >	20	16,768	Mac Applications and Mac App Store
	Teacher accuses student using linux of copyright infringement! (1 2 3) LeoFio	Dec 15, 2008 10:14 AM by dilbert4life >	56	1,763	Community Discussion
	Timemachine Duplicates? MBX	Nov 27, 2008 09:16 AM by scuac >	18	2,206	Mac OS X

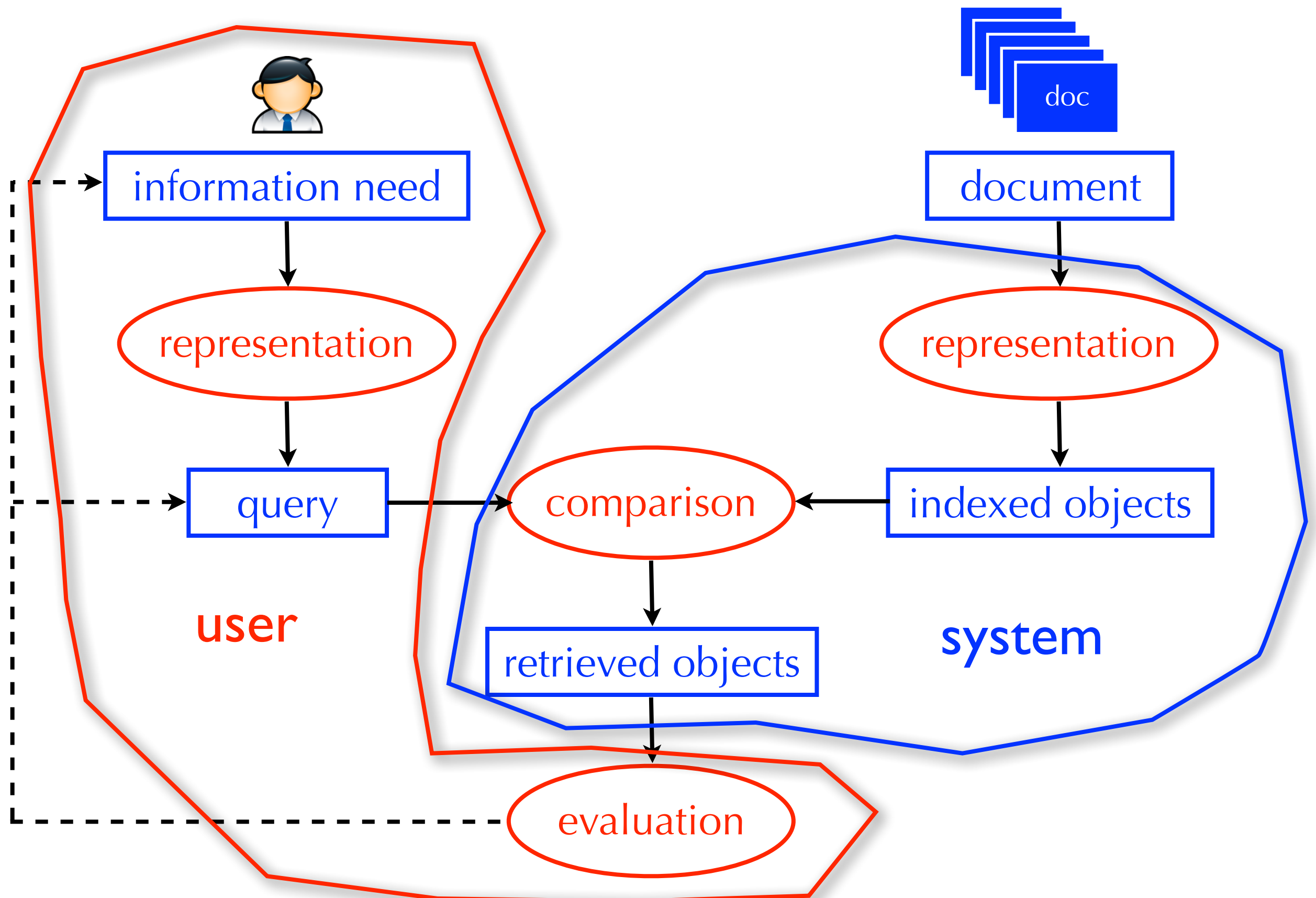
Ad-hoc Retrieval

- We will focus on **non-web** ad-hoc retrieval
 - ▶ more is known about how these systems work
 - ▶ more stable solutions - not constantly tweaked
 - ▶ not heavily tuned using user-interaction data (e.g., clicks)
 - ▶ very common: digital libraries, government and corporate intranets, large information service providers (e.g., Thompson Reuters), social media, your own personal computers

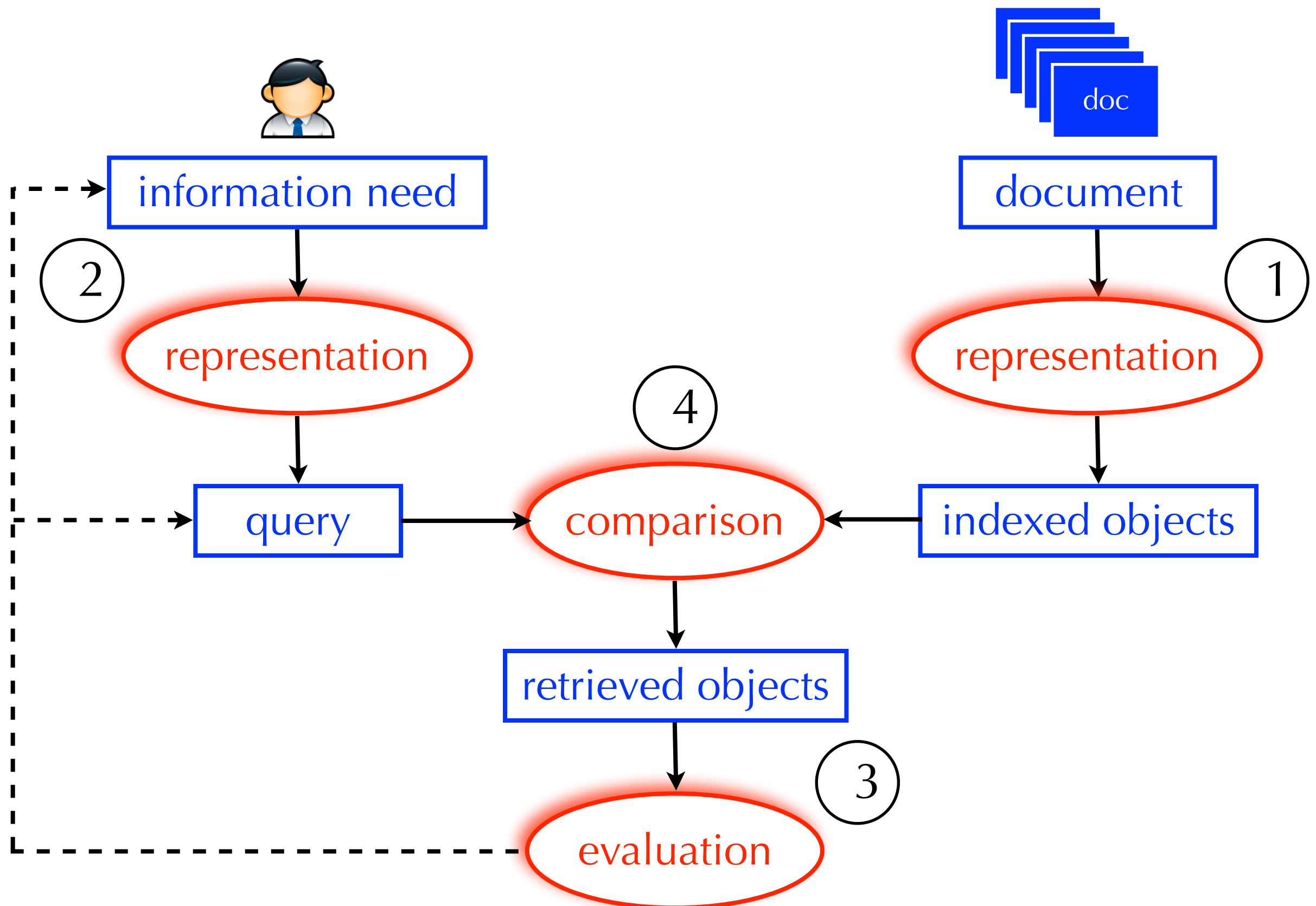
Basic Information Retrieval Process



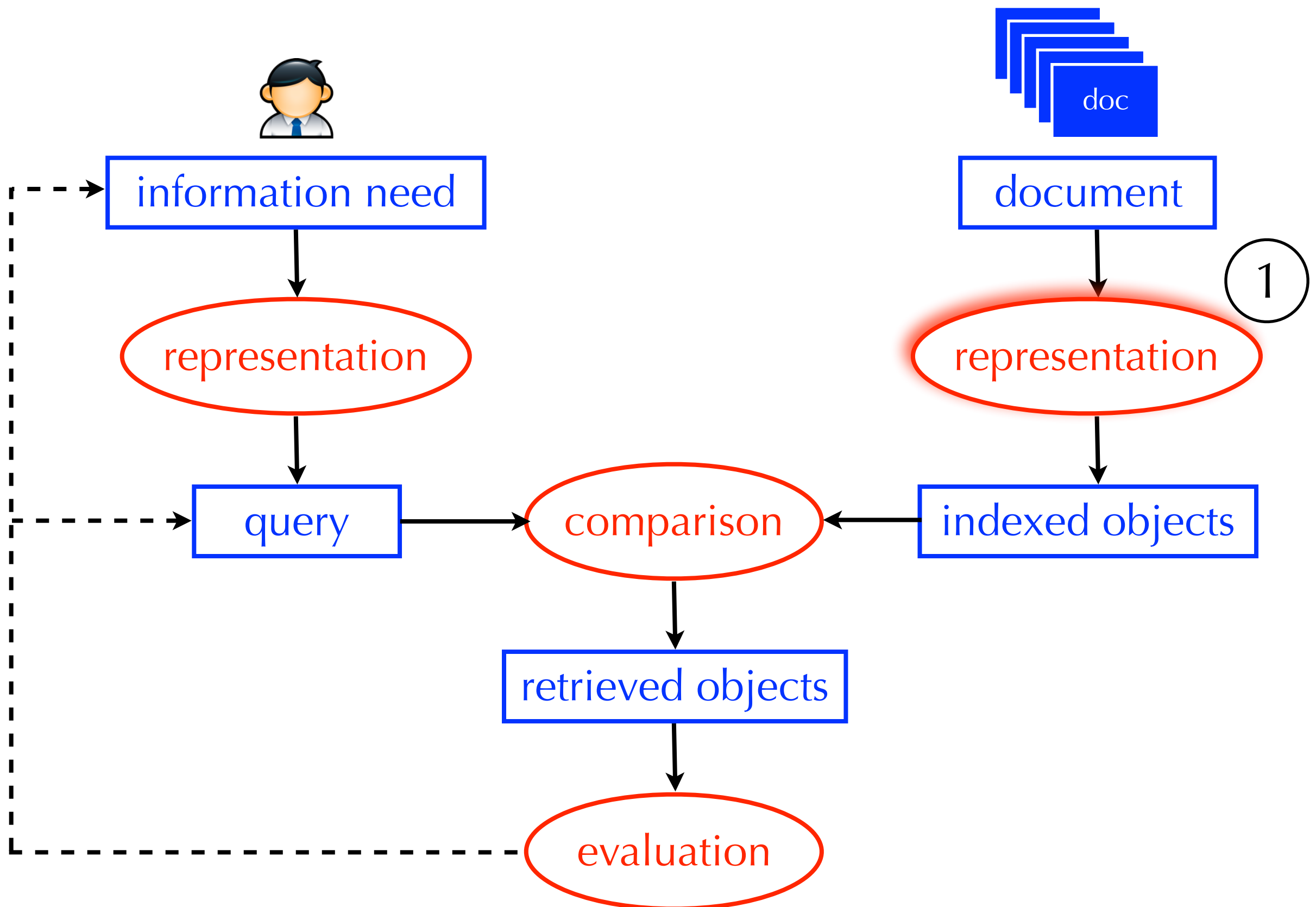
Basic Information Retrieval Process



Next Two Lectures



Document Representation



Most Basic View of a Search Engine

- A search engines does not scan each document to see if it satisfies the query
- It uses an index to quickly locate the relevant documents
- **Index:** a list of concepts with pointers to documents (in this case, pages) that discuss them

L_2 distance, 131
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 δ codes, 104
 γ encoding, 99
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 k -gram index, 54, 60
1/0 loss, 221
11-point interpolated average precision, 159
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average-link clustering, 389

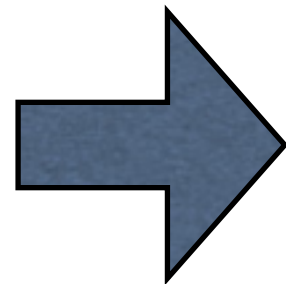
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bag-of-words, 269
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break-even point, 161
BSBI, 71
Buckshot algorithm, 399
buffer, 69

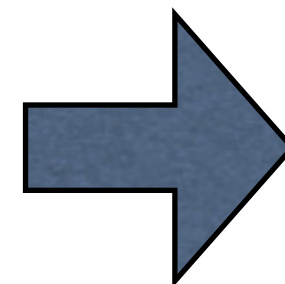
caching, 9, 68, 146, 447, 450
capture-recapture method, 435
cardinality
 in clustering, 355
CAS topics, 211
case-folding, 30

Most Basic View of a Search Engine

input query:
A/B testing



L_2 distance, 131	Bayes' Rule, 220
χ^2 feature selection, 275	Bayesian networks, 234
δ codes, 104	Bayesian prior, 226
γ encoding, 99	Bernoulli model, 263
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bag of words, 117, 267	buffer, 69
bag-of-words, 269	caching, 9, 68, 146, 447, 450
balanced F measure, 156	capture-recapture method, 435
Bayes error rate, 300	cardinality
Bayes Optimal Decision Rule, 222	in clustering, 355
Bayes risk, 222	CAS topics, 211
	case-folding, 30



output
document:
docid: 170

- So, what goes in the index is important!
- How might we combine concepts (e.g., patent search + A/B testing)?

Document Representation

- **Document representation:** deciding what concepts should go in the index
- **Option 1 (controlled vocabulary):** a set a manually constructed concepts that describe the major topics covered in the collection
- **Option 2 (free-text indexing):** the set of individual terms that occur in the collection

Document Representation

- If we view **option 1** and **option 2** as two extremes, where does this particular index fit in?

L_2 distance, 131
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B-tree, 50
bag of words, 117, 267
bag-of-words, 269
balanced F measure, 156
Bayes error rate, 300
Bayes Optimal Decision Rule, 222
Bayes risk, 222

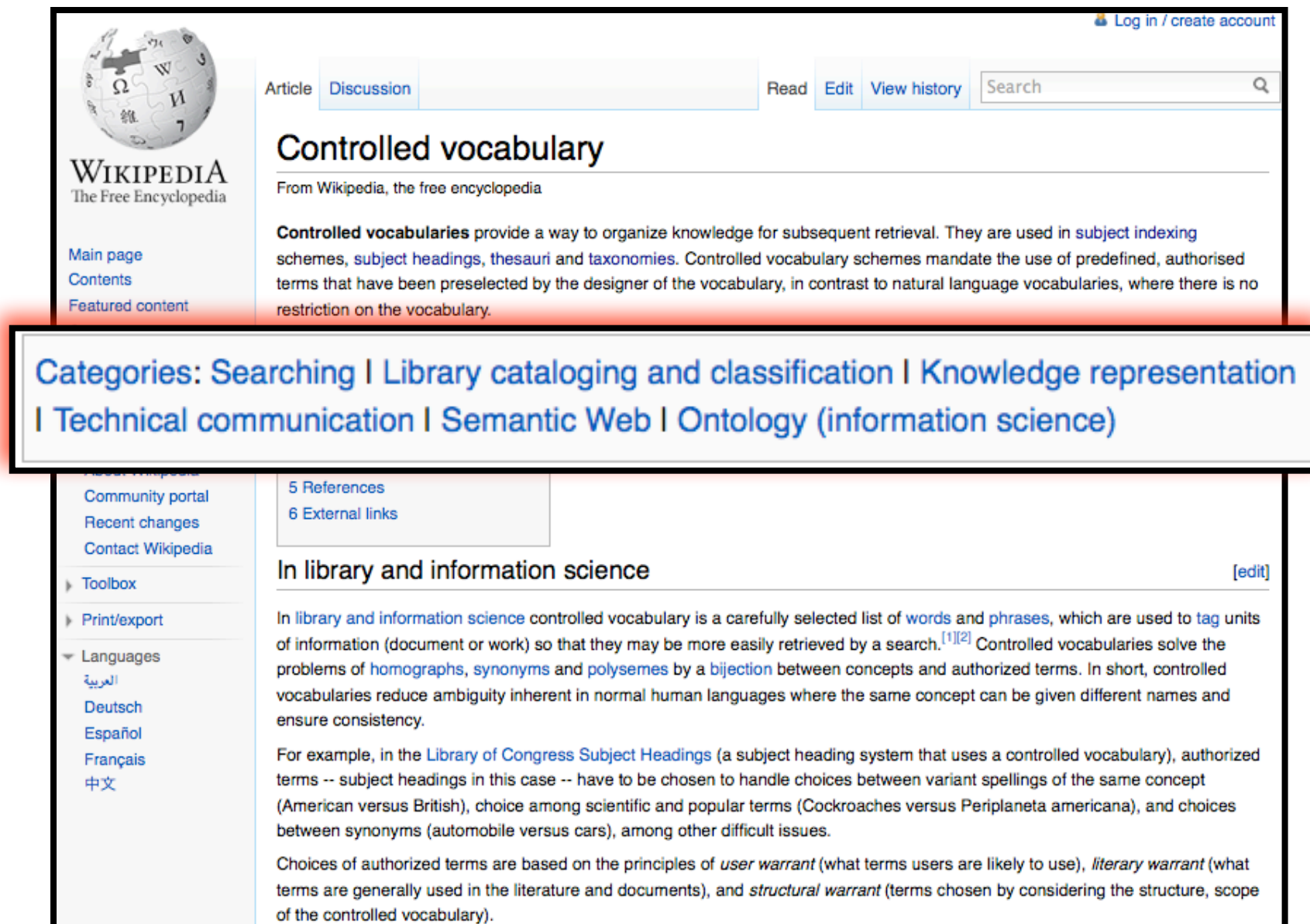
Bayes' Rule, 220
Bayesian networks, 234
Bayesian prior, 226
Bernoulli model, 263
best-merge persistence, 388
bias, 311
bias-variance tradeoff, 241, 312, 321
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Buckshot algorithm, 399
buffer, 69

caching, 9, 68, 146, 447, 450
capture-recapture method, 435
cardinality
 in clustering, 355
CAS topics, 211
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Document Representation

option 1: controlled vocabulary

- **Controlled vocabulary:** a set of well-defined concepts
- Assigned to documents by humans (or automatically)



The screenshot shows a Wikipedia article page for "Controlled vocabulary". The page layout includes a sidebar on the left with the Wikipedia logo and navigation links (Main page, Contents, Featured content, Community portal, Recent changes, Contact Wikipedia, Toolbox, Print/export, Languages). The main content area has tabs for "Article" and "Discussion", and buttons for "Read", "Edit", and "View history". A search bar is located in the top right. The article text explains that controlled vocabularies are used for organizing knowledge for retrieval, mentioning subject indexing schemes, subject headings, thesauri, and taxonomies. It contrasts controlled vocabularies with natural language vocabularies. A red box highlights a section titled "Categories: Searching | Library cataloging and classification | Knowledge representation | Technical communication | Semantic Web | Ontology (information science)". Below this, there is a section titled "In library and information science" with an [edit] link. This section discusses how controlled vocabularies are used to tag units of information for easier retrieval, solving problems of homographs, synonyms, and polysemes through a bijection between concepts and authorized terms. It provides examples from the Library of Congress Subject Headings and discusses the principles of user warrant, literary warrant, and structural warrant.

WIKIPEDIA
The Free Encyclopedia

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Controlled vocabulary

From Wikipedia, the free encyclopedia

Controlled vocabularies provide a way to organize knowledge for subsequent retrieval. They are used in [subject indexing](#) schemes, [subject headings](#), [thesauri](#) and [taxonomies](#). Controlled vocabulary schemes mandate the use of predefined, authorised terms that have been preselected by the designer of the vocabulary, in contrast to natural language vocabularies, where there is no restriction on the vocabulary.

Categories: [Searching](#) | [Library cataloging and classification](#) | [Knowledge representation](#) | [Technical communication](#) | [Semantic Web](#) | [Ontology \(information science\)](#)

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In library and information science [edit]

In [library and information science](#) controlled vocabulary is a carefully selected list of [words](#) and [phrases](#), which are used to [tag](#) units of information (document or work) so that they may be more easily retrieved by a search.^{[1][2]} Controlled vocabularies solve the problems of [homographs](#), [synonyms](#) and [polysemes](#) by a [bijection](#) between concepts and authorized terms. In short, controlled vocabularies reduce ambiguity inherent in normal human languages where the same concept can be given different names and ensure consistency.


For example, in the [Library of Congress Subject Headings](#) (a subject heading system that uses a controlled vocabulary), authorized terms -- subject headings in this case -- have to be chosen to handle choices between variant spellings of the same concept (American versus British), choice among scientific and popular terms (Cockroaches versus *Periplaneta americana*), and choices between synonyms (automobile versus cars), among other difficult issues.

Choices of authorized terms are based on the principles of *user warrant* (what terms users are likely to use), *literary warrant* (what terms are generally used in the literature and documents), and *structural warrant* (terms chosen by considering the structure, scope of the controlled vocabulary).

Document Representation

option 1: controlled vocabulary

- Controlled vocabulary: a set of well-defined concepts
- Assigned to documents



WIKIPEDIA
The Free Encyclopedia

Article Discussion

Controlled v

From Wikipedia, the free e

Controlled vocabularies schemes, subject heading terms that have been pr restriction on the vocabu

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6 External links

In library and inf

In library and information of information (document problems of homograph vocabularies reduce am ensure consistency.

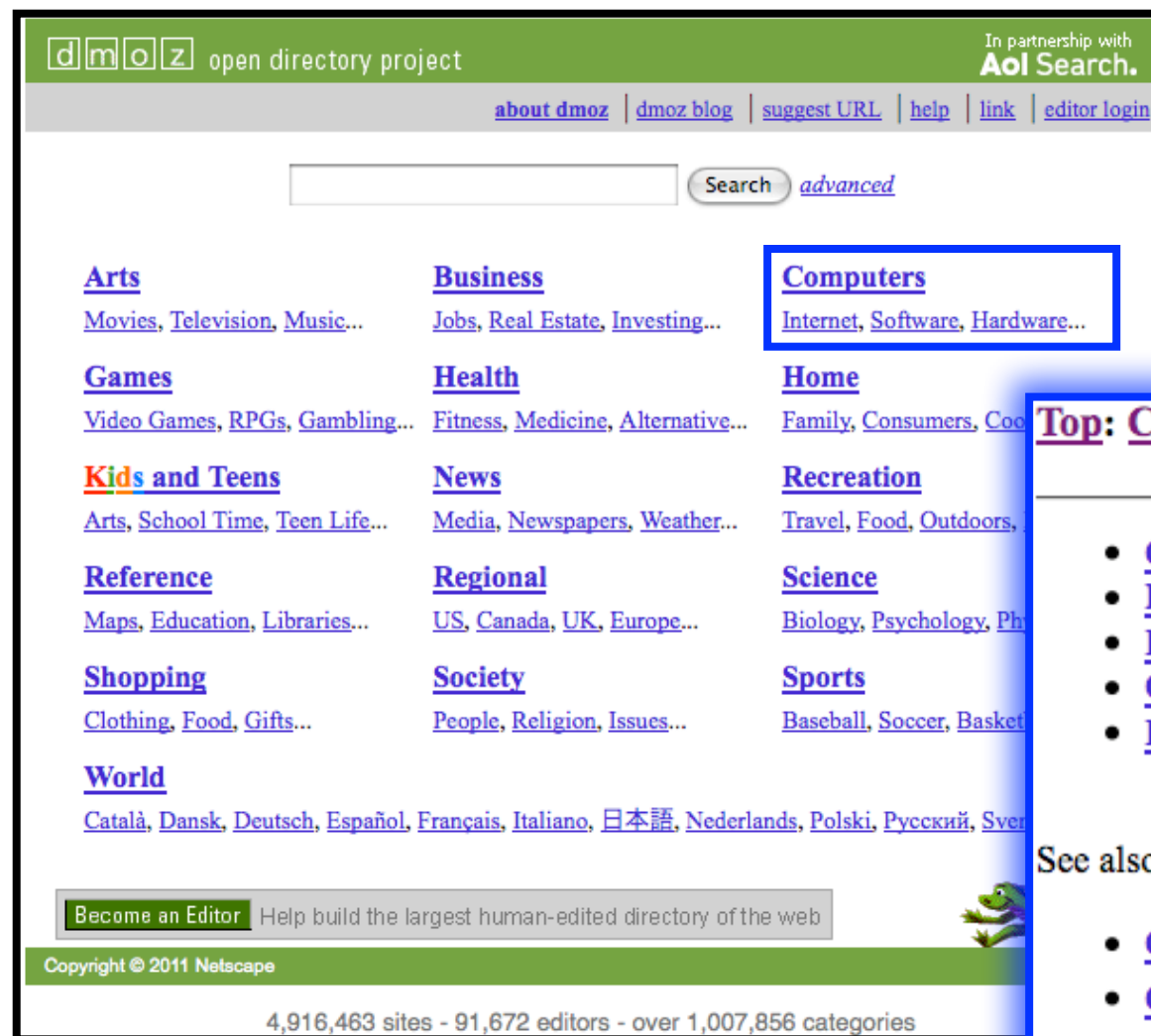
For example, in the Libr terms -- subject heading (American versus British between synonyms (aut

Choices of authorized te terms are generally used of the controlled vocabulary).

<p>A</p> <ul style="list-style-type: none"> Adversarial information retrieval Agrep Approximate string matching <p>C</p> <ul style="list-style-type: none"> Concordance (publishing) Contextual Query Language Controlled vocabulary <p>D</p> <ul style="list-style-type: none"> Daffodil (software) Desktop search <p>E</p> <ul style="list-style-type: none"> Enterprise search List of enterprise search vendors <p>F</p> <ul style="list-style-type: none"> Federated search Find Full text search <p>H</p> <ul style="list-style-type: none"> Hybrid search engine 	<p>I</p> <ul style="list-style-type: none"> IBM Omnifind Index (search engine) Indexing Service Information needs IR evaluation <p>K</p> <ul style="list-style-type: none"> Key Word in Context <p>M</p> <ul style="list-style-type: none"> Multimedia search <p>N</p> <ul style="list-style-type: none"> Nearest neighbor search <p>O</p> <ul style="list-style-type: none"> OpenGrok <p>P</p> <ul style="list-style-type: none"> Poison words PolySpot Ptx (Unix) <p>Q</p> <ul style="list-style-type: none"> Query expansion 	<p>R cont.</p> <ul style="list-style-type: none"> Reverse telephone directory <p>S</p> <ul style="list-style-type: none"> Search-oriented architecture Search/Retrieve via URL Social search Statistically Improbable Phrases Stop words <p>T</p> <ul style="list-style-type: none"> Term indexing <p>U</p> <ul style="list-style-type: none"> Unified Information Access <p>V</p> <ul style="list-style-type: none"> Vertical search <p>W</p> <ul style="list-style-type: none"> Web harvesting Web indexing <p>Y</p> <ul style="list-style-type: none"> Yebol Yovisto
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Controlled Vocabularies

- May include (parent-child) relations b/w concepts
- Facilitates non-query-based browsing and exploration



Open Directory Project (ODP)

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- Data Clustering@ (166)
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See also:

- Computers: Software: File Management: Search (37)
- Computers: Software: Internet: Servers: Search (41)
- Reference: Knowledge Management: Knowledge Retrieval (40)
- Reference: Libraries: Library and Information Science: Software (93)

Controlled Vocabularies

















example

- **MeSH:** Medical Subject Headings
- Created by the National Library of Medicine to index biomedical journals and books
- About 25,000 subject headings arranged in a hierarchy
- Used to search PubMed



Controlled Vocabularies

example

1.  Anatomy [A]
2.  Organisms [B]
3.  Diseases [C]
4.  Chemicals and Drugs [D]
5.  Analytical, Diagnostic and Therapeutic Techniques and Equipment [E]
6.  Psychiatry and Psychology [F]
7.  Phenomena and Processes [G]
8.  Disciplines and Occupations [H]
9.  Anthropology, Education, Sociology and Social Phenomena [I]
10.  Technology, Industry, Agriculture [J]
11.  Humanities [K]
12.  Information Science [L]
13.  Named Groups [M]
14.  Health Care [N]
15.  Publication Characteristics [V]
16.  Geographicals [Z]

Controlled Vocabularies

example

1. ☒ Anatomy [A]
2. ☒ Organisms [B]
 - ☒ Eukaryota [B01] ☒
 - ☒ Archaea [B02] ☒
 - ☒ Bacteria [B03] ☒
 - ☒ Viruses [B04] ☒
 - ☒ Organism Forms [B05] ☒
3. ☒ Diseases [C]
4. ☒ Chemicals and Drugs [D]
5. ☒ Analytical, Diagnostic and Therapeutic Techniques and Equipment [E]
6. ☒ Psychiatry and Psychology [F]
7. ☒ Phenomena and Processes [G]
8. ☒ Disciplines and Occupations [H]
9. ☒ Anthropology, Education and Society [J]
10. ☒ Technology, Industry, Agriculture [L]
11. ☒ Humanities [K]
12. ☒ Information Science [L]
13. ☒ Named Groups [M]
14. ☒ Health Care [N]
15. ☒ Publication Characteristics [P]
16. ☒ Geographicals [Z]

MeSH Heading	Eukaryota
Tree Number	B01
Annotation	do not confuse with EUKARYOTIC CELLS ; specific algae and protozoa are located under various groups treed under Eukaryota
Scope Note	One of the three domains of life (the others being BACTERIA and ARCHAEA), also called Eukarya. These are organisms whose cells are enclosed in membranes and possess a nucleus. They comprise almost all multicellular and many unicellular organisms, and are traditionally divided into groups (sometimes called kingdoms) including ANIMALS ; PLANTS ; FUNGI ; and various algae and other taxa that were previously part of the old kingdom Protista.
Entry Term	Eucarya
Entry Term	Eukarya
Entry Term	Eukaryotes
Allowable Qualifiers	CH CL CY DE EN GD GE IM IP ME PH PY RE UL VI
Previous Indexing	Eukaryotic Cells (1986-2009)
History Note	2010
Date of Entry	20090706
Unique ID	D056890

Controlled Vocabularies

example

1. ☒ Anatomy [A]
2. ☒ Organisms [B]
 - ☒ Eukaryota [B01] ☒
 - ☒ Archaea [B02] ☒
 - ☒ Bacteria [B03] ☒
 - ☒ Viruses [B04] ☒
 - ☒ Cellular [B05] ☒
3. ☒ Disease [D]
4. ☒ Chemistry [C]
5. ☒ Anatomy [A]
6. ☒ Psychology [P]
7. ☒ Phenomena [F]
8. ☒ Diseases [D]
9. ☒ Anthropology [H]
10. ☒ Technology, Industry, Agriculture [T]
11. ☒ Humanities [K]
12. ☒ Information Science [L]
13. ☒ Named Groups [M]
14. ☒ Health Care [N]
15. ☒ Publication Characteristics [J]
16. ☒ Geographicals [Z]

MeSH Heading	Eukaryota
Tree Number	B01
Entry Term	Eukaryotes
Allowable Qualifiers	CH CL CY DE EN GD GE IM IP ME PH PY RE UL VI
Previous Indexing	Eukaryotic Cells (1986-2009)
History Note	2010
Date of Entry	20090706
Unique ID	D056890

If you are not familiar with the term “eukaryota”, you can start to imagine a potential drawback of controlled vocabularies.

do not confuse with [EUKARYOTIC CELLS](#): specific algae and protozoa are located [A](#) and [ARCHAEA](#)), closed in membranes (prokaryotes and many unicellular organisms called kingdoms) and other taxa that were

Controlled Vocabularies

example

NCBI Resources ▾ How To ▾

MeSH MeSH light therapy Search

Phototherapy

Treatment of disease by exposure to light, especially by variously concentrated light rays or specific wavelengths.

Year introduced: 1981

PubMed search builder options

[Subheadings:](#)

sub-headings

- | | | |
|--|--|--|
| <input type="checkbox"/> adverse effects | <input type="checkbox"/> instrumentation | <input type="checkbox"/> statistics and numerical data |
| <input type="checkbox"/> classification | <input type="checkbox"/> methods | <input type="checkbox"/> supply and distribution |
| <input type="checkbox"/> contraindications | <input type="checkbox"/> nursing | <input type="checkbox"/> trends |
| <input type="checkbox"/> economics | <input type="checkbox"/> psychology | <input type="checkbox"/> utilization |
| <input type="checkbox"/> history | <input type="checkbox"/> standards | <input type="checkbox"/> veterinary |

[All MeSH Categories](#)

[Analytical, Diagnostic and Therapeutic Techniques and Equipment Category](#)

[Therapeutics](#)

Phototherapy

[Color Therapy](#)

[Heliotherapy](#)

[Laser Therapy, Low-Level](#)

[Photochemotherapy](#)

[Hematoporphyrin Photoradiation](#)

[Ultraviolet Therapy](#)

[PUVA Therapy](#) +

Entry Terms:

- Phototherapies
- Therapy, Photoradiation
- Photoradiation Therapies
- Therapies, Photoradiation
- **Light Therapy**
- Light Therapies
- Therapies, Light
- Therapy, Light
- Photoradiation Therapy

sub-tree within the hierarchy

entry-terms

Controlled Vocabularies

example

NCBI Resources ▾ How To ▾

PubMed.gov
US National Library of Medicine
National Institutes of Health

PubMed phototherapy/adverse effects Search

RSS Save search Limits Advanced

Results: 1 to 20 of 2697 << First < Prev Page 1 of 135 Next > Last >>

☐ [Burning daylight: balancing vitamin D requirements with sensible sun exposure.](#)
1. Stalgis-Bilinski KL, Boyages J, Salisbury EL, Dunstan CR, Henderson SI, Talbot PL.
Med J Aust. 2011 Apr 4;194(7):345-8.
PMID: 21470084 [PubMed - indexed for MEDLINE]
[Related citations](#)

☐ [Time-lag between subretinal fluid and pigment epithelial detachment reduction after polypoidal choroidal vasculopathy treatment.](#)
2. Chae JB, Lee JY, Yang SJ, Kim JG, Yoon YH.
Korean J Ophthalmol. 2011 Apr;25(2):98-104. Epub 2011 Mar 11.
PMID: 21461221 [PubMed - indexed for MEDLINE] **Free PMC Article**
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☐ [Metal stenting to resolve post-photodynamic therapy stricture in early esophageal cancer.](#)
3. Cheon YK.
World J Gastroenterol. 2011 Mar 14;17(10):1379-82.
PMID: 21455341 [PubMed - indexed for MEDLINE] **Free PMC Article**
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☐ [A study of multiple full-face treatments with low-energy settings of a 2940-nm Er:YAG fractionated laser.](#)
4. Goldberg DJ, Hussain M.
J Cosmet Laser Ther. 2011 Apr;13(2):42-6.
PMID: 21401375 [PubMed - indexed for MEDLINE]
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Controlled Vocabularies

example

Burning daylight: balancing vitamin D requirements with sensible sun exposure.

Stalgis-Bilinski KL, Boyages J, Salisbury EL, Dunstan CR, Henderson SI, Talbot PL.

Westmead Breast Cancer Institute, University of Sydney, Sydney, NSW, Australia. Kellie.Bilinski@bci.org.au

Abstract

OBJECTIVE: To examine the feasibility of balancing sunlight exposure to meet vitamin D requirements with sun protection guidelines.

DESIGN AND SETTING: We used standard erythema dose and Ultraviolet Index (UVI) data for 1 June 1996 to 30 December 2005 for seven Australian cities to estimate duration of sun exposure required for fair-skinned individuals to synthesise 1000 IU (25 µg) of vitamin D, with 11% and 17% body exposure, for each season and hour of the day. Periods were classified according to whether the UVI was < 3 or ≥ 3 (when sun protection measures are recommended), and whether required duration of exposure was ≤ 30 min, 31-60 min, or > 60 min.

MAIN OUTCOME MEASURE: Duration of sunlight exposure required to achieve 1000 IU of vitamin D synthesis.

RESULTS: Duration of sunlight exposure required to synthesise 1000 IU of vitamin D varied by time of day, season and city. Although peak UVI periods are typically promoted as between 10 am and 3 pm, UVI was often ≥ 3 before 10 am or after 3 pm. When the UVI was < 3, there were few opportunities to synthesise 1000 IU of vitamin D within 30 min, with either 11% or 17% body exposure.

CONCLUSION: There is a delicate line between balancing the beneficial effects of sunlight exposure while avoiding its damaging effects. Physiological and geographical factors may reduce vitamin D synthesis, and supplementation may be necessary to achieve adequate vitamin D status for individuals at risk of deficiency.

MeSH Terms

Australia

Dose-Response Relationship, Radiation

Guideline Adherence

Health Policy*

Heliotherapy/adverse effects

Heliotherapy/methods*

Humans

Seasons

Skin Pigmentation

Sunlight/adverse effects*

Time Factors

Vitamin D/biosynthesis*

Vitamin D Deficiency/prevention & control*

Controlled Vocabularies

advantages

- Concepts do not need to appear explicitly in the text
- Relationships between concepts facilitate non-query-based navigation and exploration (e.g., ODP)
- Developed by experts who know the data and the users
- Represent the concepts/relationships that users (presumably) care the most about
- Describe the concepts that are most central to the document
- Concepts are unambiguous and recognizable (necessary for annotators and good for users)

Document Representation

option 2: free-text indexing

- Represent documents using terms within the document
- Which terms? Only the most descriptive terms? Only the unambiguous ones? All of them?
- Usually, all of them (a.k.a. full-text indexing)
- The user will use term-combinations to express higher level concepts
- Query terms will hopefully disambiguate each other (e.g., “volkswagen golf”)
- The search engine will determine which terms are important (we’ll talk about this during “retrieval models”)

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Salton was perhaps most well known for developing the now widely used [Vector Space Model](#) for Information Retrieval^[1]. In this model, both documents and queries are represented as vectors of term counts, and the similarity between a document and a query is given by the cosine between the term vector and the document vector. In this paper, he also introduced [TF-IDF](#), or term-frequency-inverse-document frequency, a model in which the score of a term in the a document is the ratio of the number of terms in that document divided by the frequency of the number of documents in which that term occurs. (The concept of inverse document frequency, a measure of specificity, had been introduced in 1972 by [Karen Sparck-Jones](#)^[2].) Later in life, he became interested in automatic text summarization and analysis^[3], as well as automatic hypertext generation^[4]. He published over 150 research articles and 5 books during his life.

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Salton was perhaps most famous for his work on the vector space model. In this model, both documents and queries are represented as vectors in a high-dimensional space. The similarity between a document and a query is measured by the cosine of the angle between their vectors. Salton introduced **TF-IDF**, or Term Frequency-Inverse Document Frequency, which is the ratio of the number of times a term occurs in a document to the number of documents in which that term occurs. He also developed the **SMART** Information Retrieval System, which he initiated when he was at Harvard.


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`<p>Gerard Salton (8 March 1927 in`

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Free-text Indexing

mark-up

- Describes how the content should be presented
 - ▶ e.g., your browser interprets HTML mark-up and presents the page as intended by the author
- Can also define relationships with other documents (e.g., hyperlinks)
- Can provide evidence of what text is important for search
- It may also provide useful, “unseen” information!

Free-text Indexing

mark-up



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`ACM`

Free-text Indexing

text-processing

<p>Gerard Salton (8 March 1927 in Nuremberg - 28 August 1995), also known as Gerry Salton, was a Professor of Computer Science at Cornell University. Salton was perhaps the leading computer scientist working in the field of information retrieval during his time. His group at Cornell developed the SMART Information Retrieval System, which he initiated when he was at Harvard.</p>

- Step 1: mark-up removal

Free-text Indexing

text-processing

Gerard Salton (8 March 1927 in Nuremberg 28 August 1995), also known as Gerry Salton, was a Professor of Computer Science at Cornell University. Salton was perhaps the leading computer scientist working in the field of information retrieval during his time. His group at Cornell developed the SMART Information Retrieval System, which he initiated when he was at Harvard.

- Step 1: mark-up removal

Free-text Indexing

text-processing

gerard salton (8 march 1927 in nuremberg 28 august 1995), also known as gerry salton, was a Professor of computer science at cornell university . salton was perhaps the leading computer scientist working in the field of information retrieval during his time. his group at cornell developed the smart information retrieval system , which he initiated when he was at harvard.

- Step 2: down-casing
- Can change a word's meaning, but we do it anyway
 - ▶ Information = information ???
 - ▶ SMART = smart ???

Free-text Indexing

text-processing

gerard salton 8 march 1978 in nuremberg 28 august 1995 also know as gerry salton was professor of computer science at cornell university salton was perhaps the leading computer scientist working in the field of information retrieval during his time his group at cornell developed the smart information retrieval system which he initiated when he was at harvard

- Step 3: tokenization
- **Tokenization:** splitting text into words (in this case, based on sequences of non-alphanumeric characters)
- Problematic cases: ph.d. = ph d, isn't = isn t

Free-text Indexing

text-processing

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- Step 4: stopword removal
- **Stopwords:** words that we choose to ignore because we expect them to not be useful in distinguishing between relevant/non-relevant documents for any query

Free-text Indexing

text-processing

gerard salton 8 march 1978 nuremberg 28 august 1995 know gerry salton
professor computer science cornell university salton perhaps
leading computer scientist working field information retrieval
time group cornell developed smart information retrieval system
initiated harvard

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text-processing

gerard salton 8 march 1978 nuremberg 28 august 1995 gerry salton professor
computer science cornell university salton leading computer scientist working field
information retrieval during time group cornell developed smart information retrieval
system initiated harvard

- **Step 5:** do this to every document in the collection and create an index using the all terms appearing in the collection

Document Representation

controlled vocabulary vs. free-text indexing

	Cost of assigning index terms	Ambiguity of index terms	Detail of representation
Controlled Vocabularies	High/Low?	Ambiguous/ Unambiguous?	Can represent arbitrary level of detail?
Free-text Indexing	High/Low?	Ambiguous/ Unambiguous?	Can represent arbitrary level of detail?

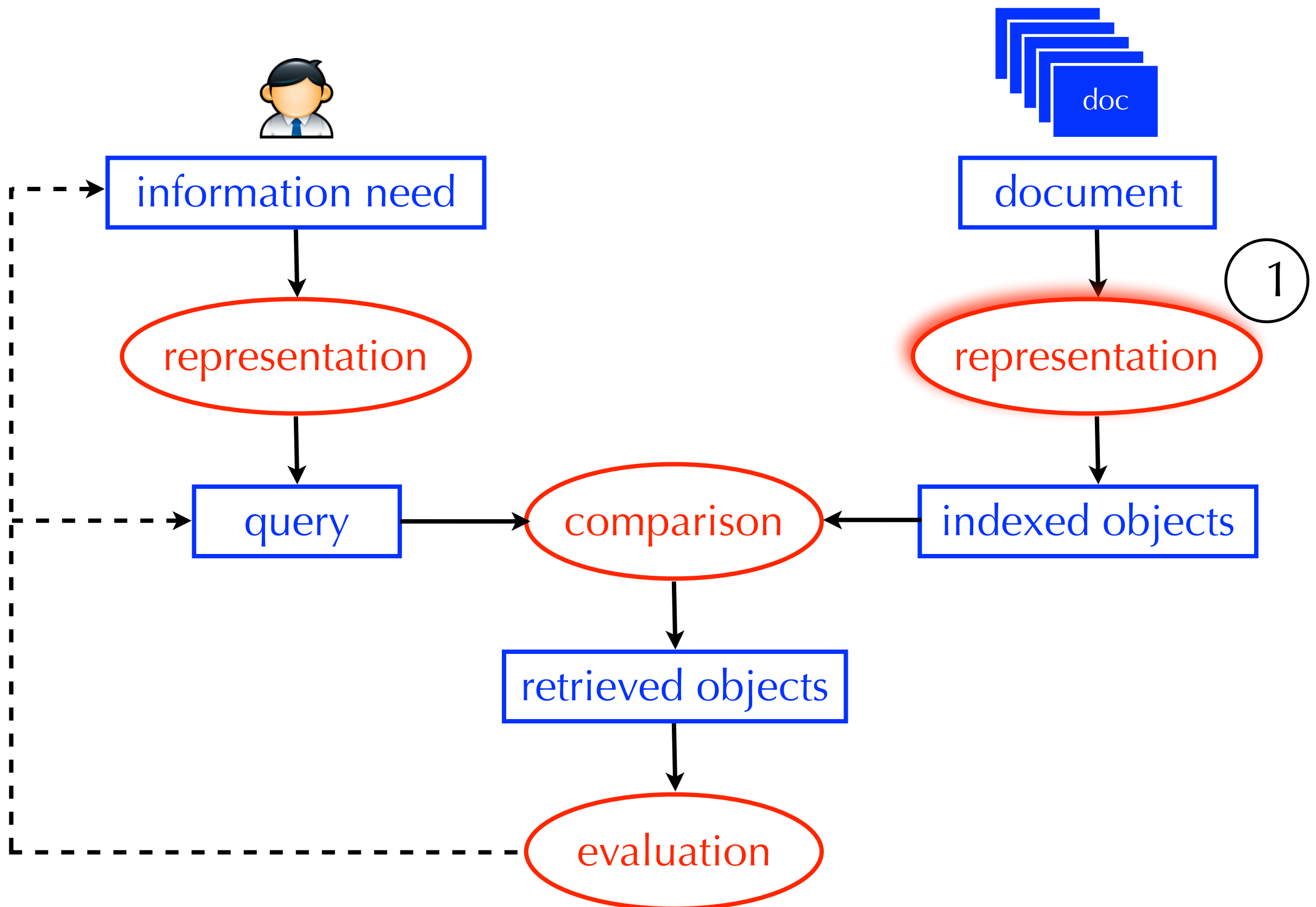
Document Representation

controlled vocabulary vs. free-text indexing

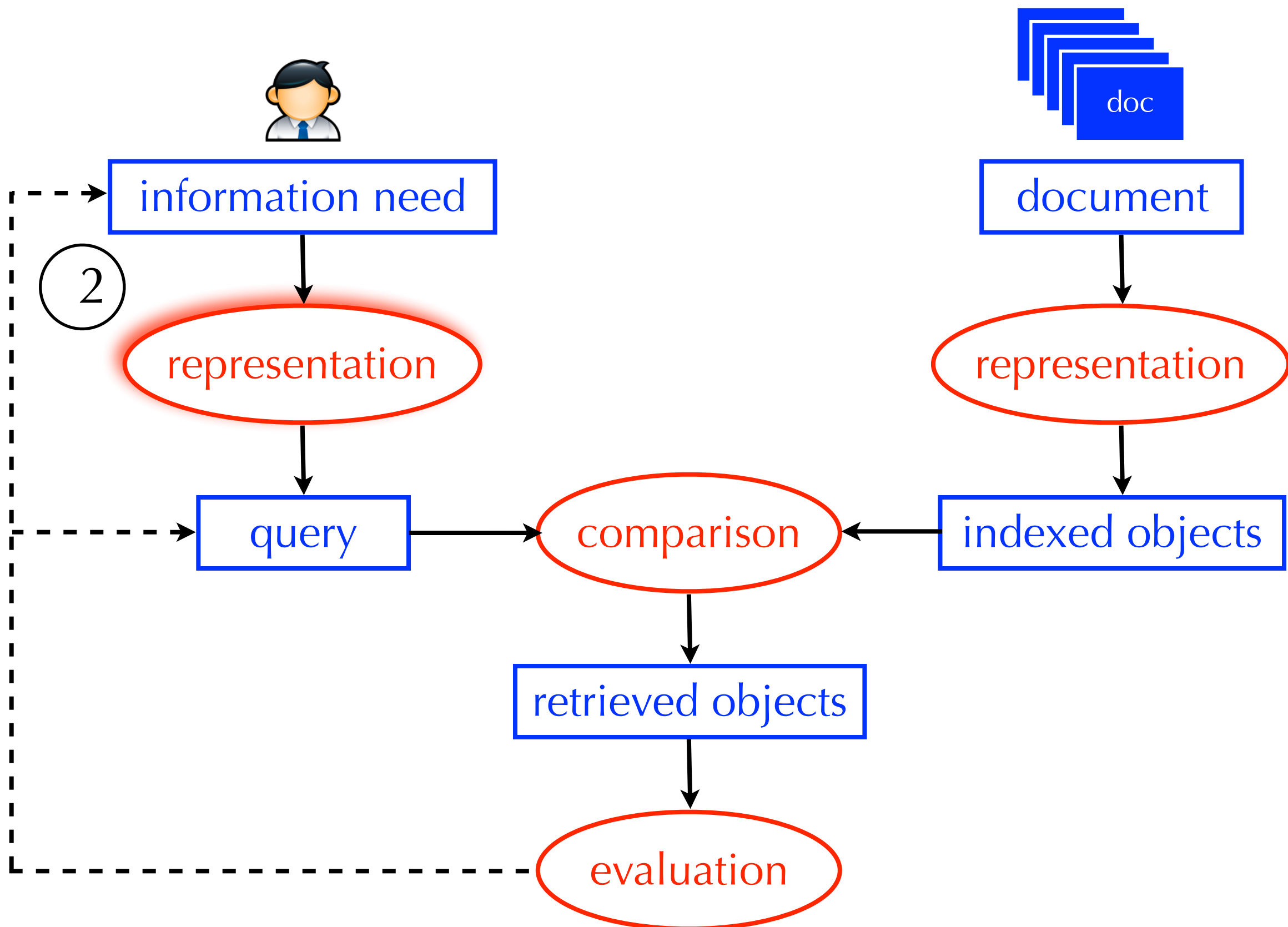
	Cost of assigning index terms	Ambiguity of index terms	Detail of representation
Controlled Vocabularies	High	Not ambiguous	Can't represent arbitrary detail
Free-text Indexing	Low	Can be ambiguous	Any level of detail

- Both are effective and used often
- We will focus on free-text indexing in this course
 - ▶ cheap and easy
 - ▶ most search engines use it (even those that adopt a controlled vocabulary)

Document Representation



Information Need Representation

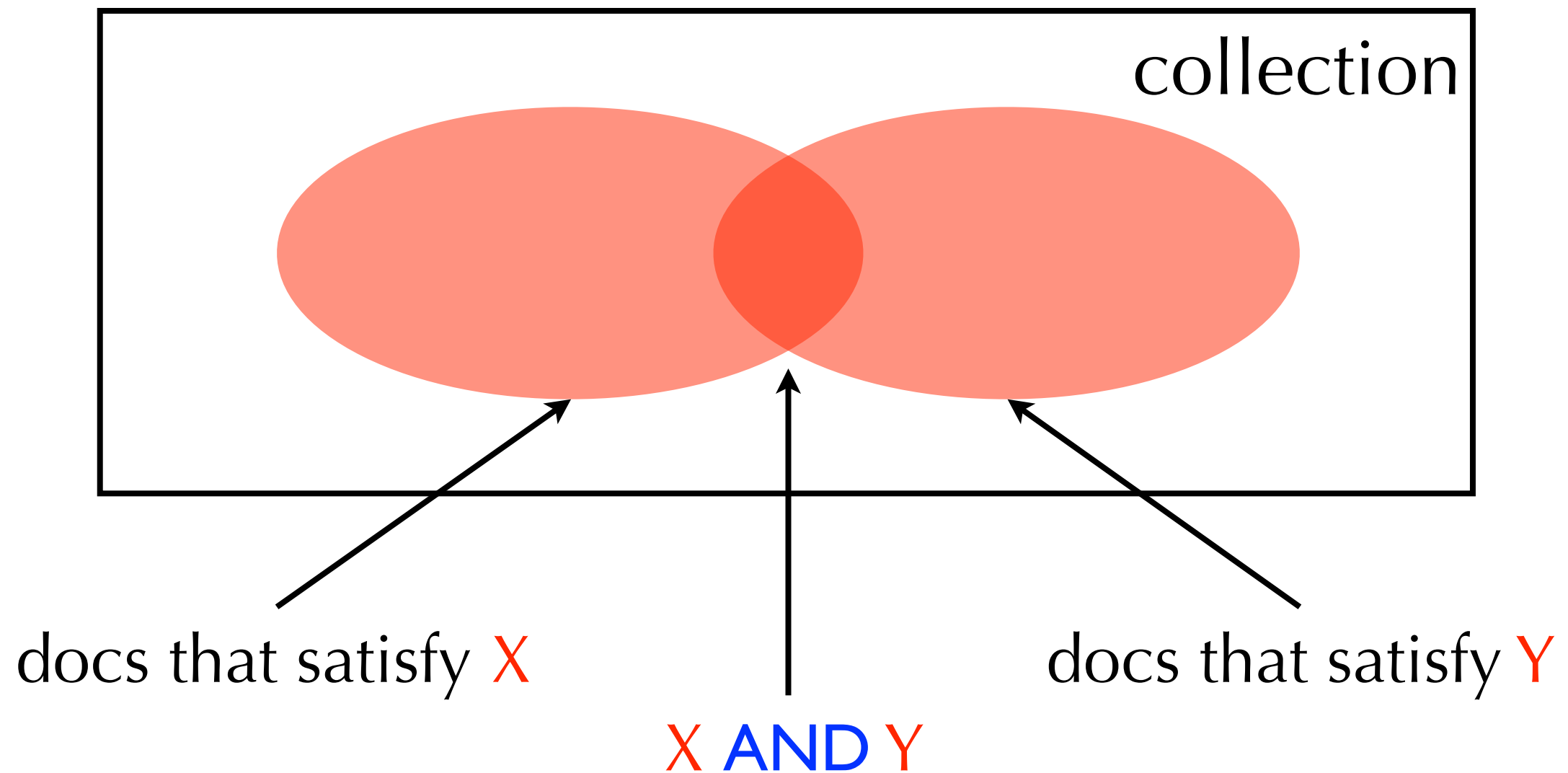


Boolean Retrieval

- **Assumption:** the user can represent their information need using boolean constraints: **AND**, **OR**, and **AND NOT**
 - ▶ lincoln
 - ▶ president **AND** lincoln
 - ▶ president **AND** (lincoln **OR** abraham)
 - ▶ president **AND** (lincoln **OR** abraham) **AND NOT** car
 - ▶ president **AND** (lincoln **OR** abraham) **AND NOT** (car **OR** automobile)
- Parentheses specify the order of operations
 - ▶ A **OR** (B **AND** C) does not equal (A **OR** B) **AND** C

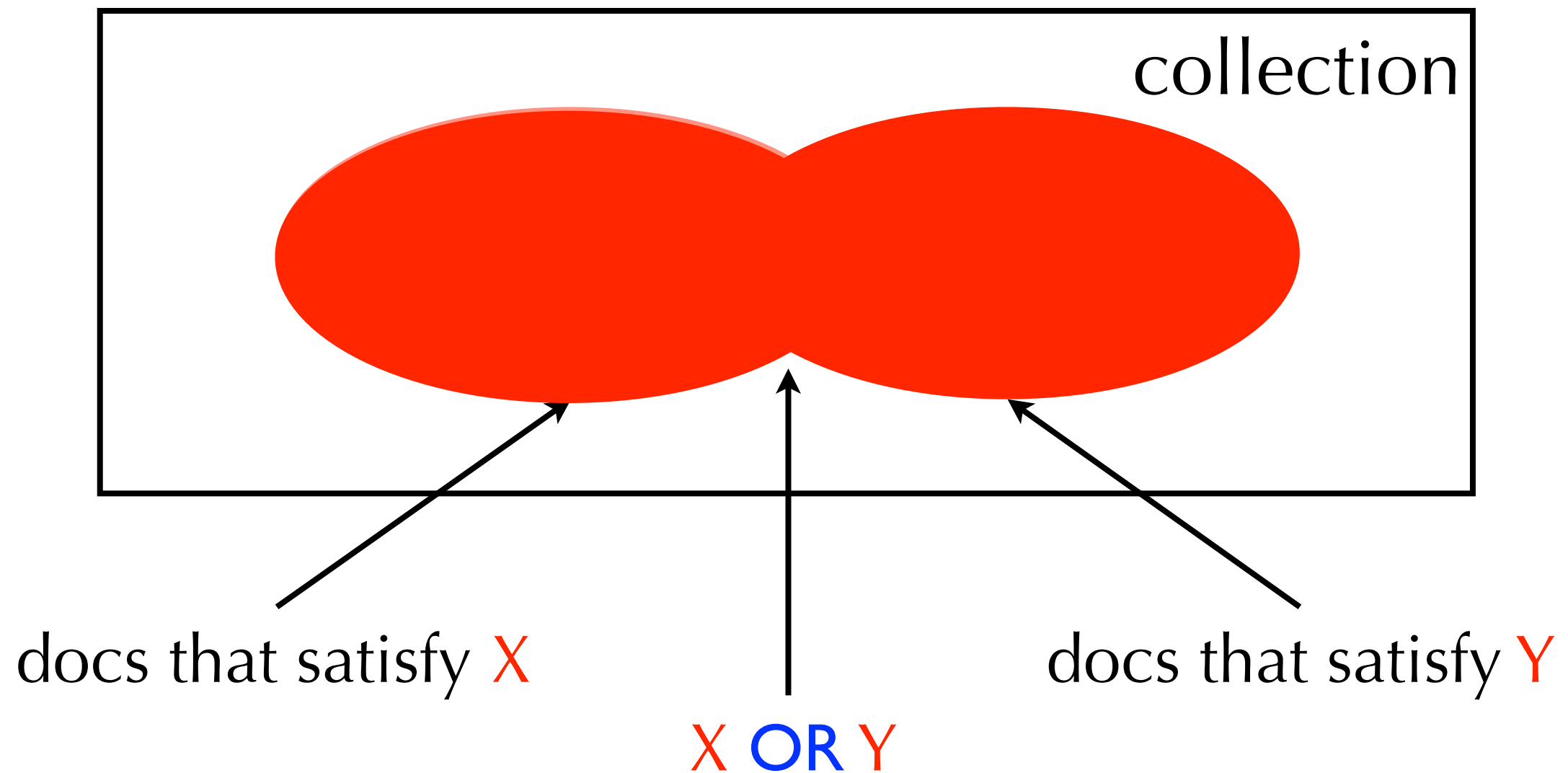
Boolean Retrieval

- $X \text{ AND } Y$



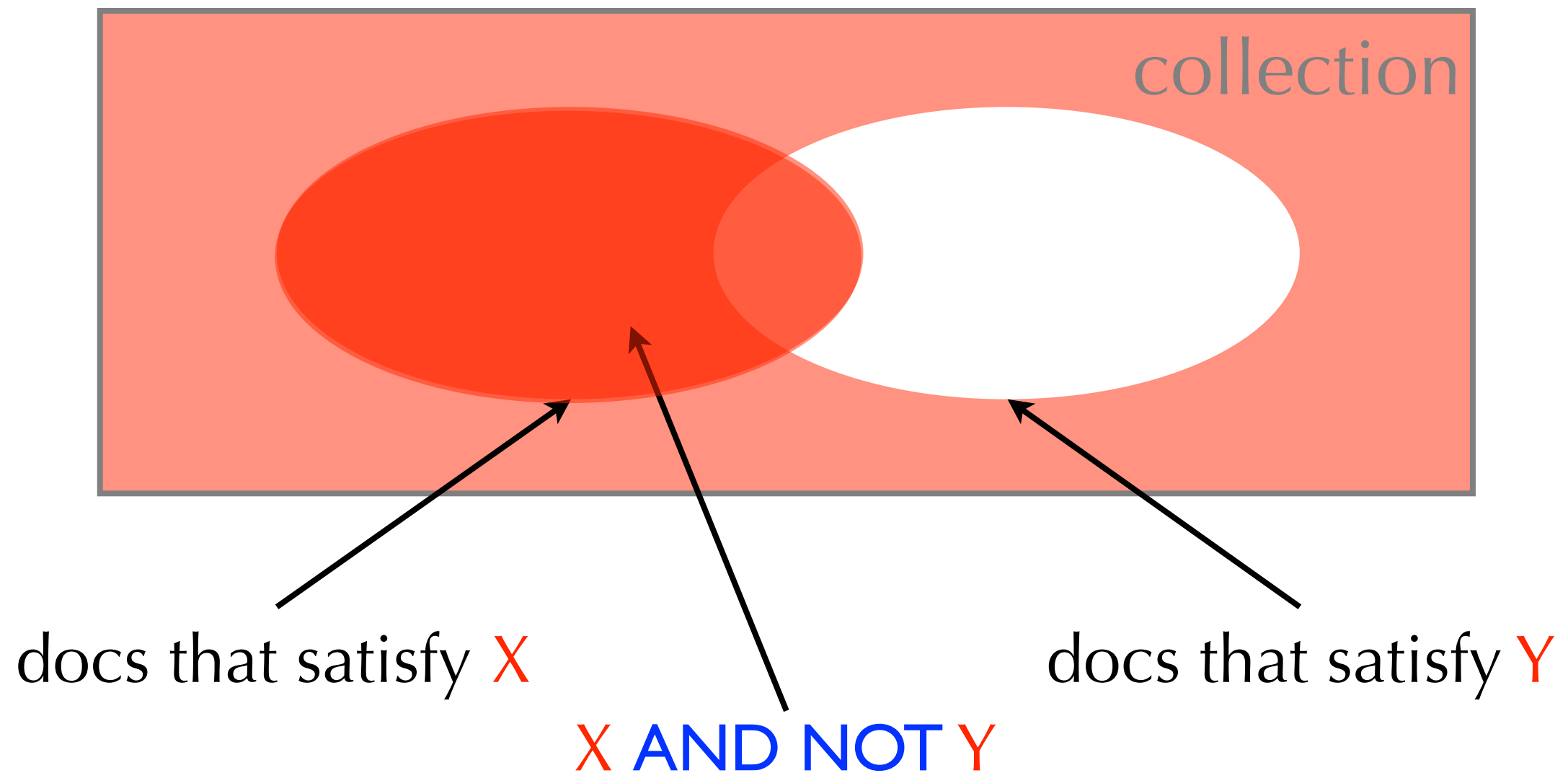
Boolean Retrieval

- $X \text{ OR } Y$



Boolean Retrieval

- $X \text{ AND NOT } Y$

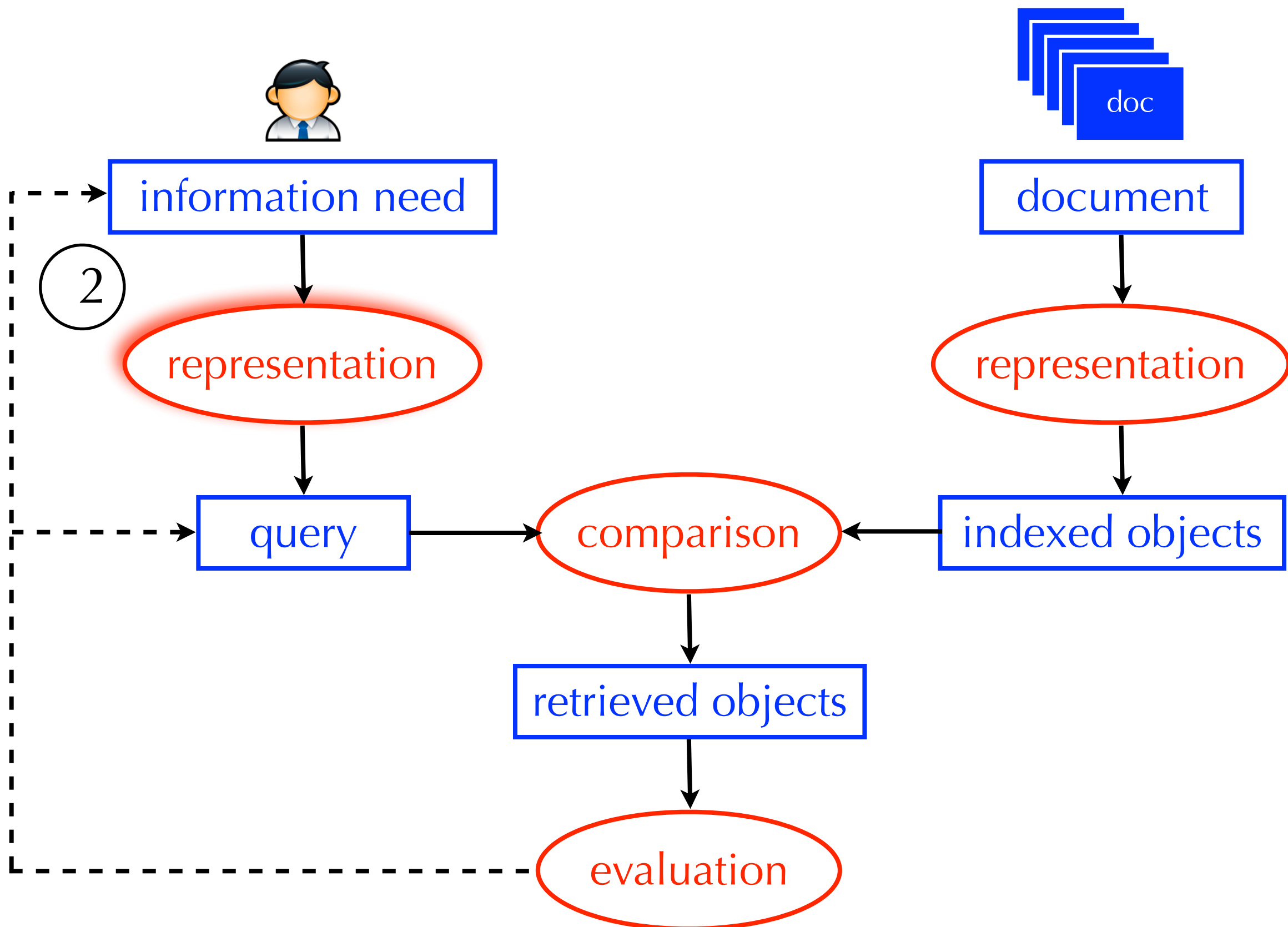


Boolean Retrieval

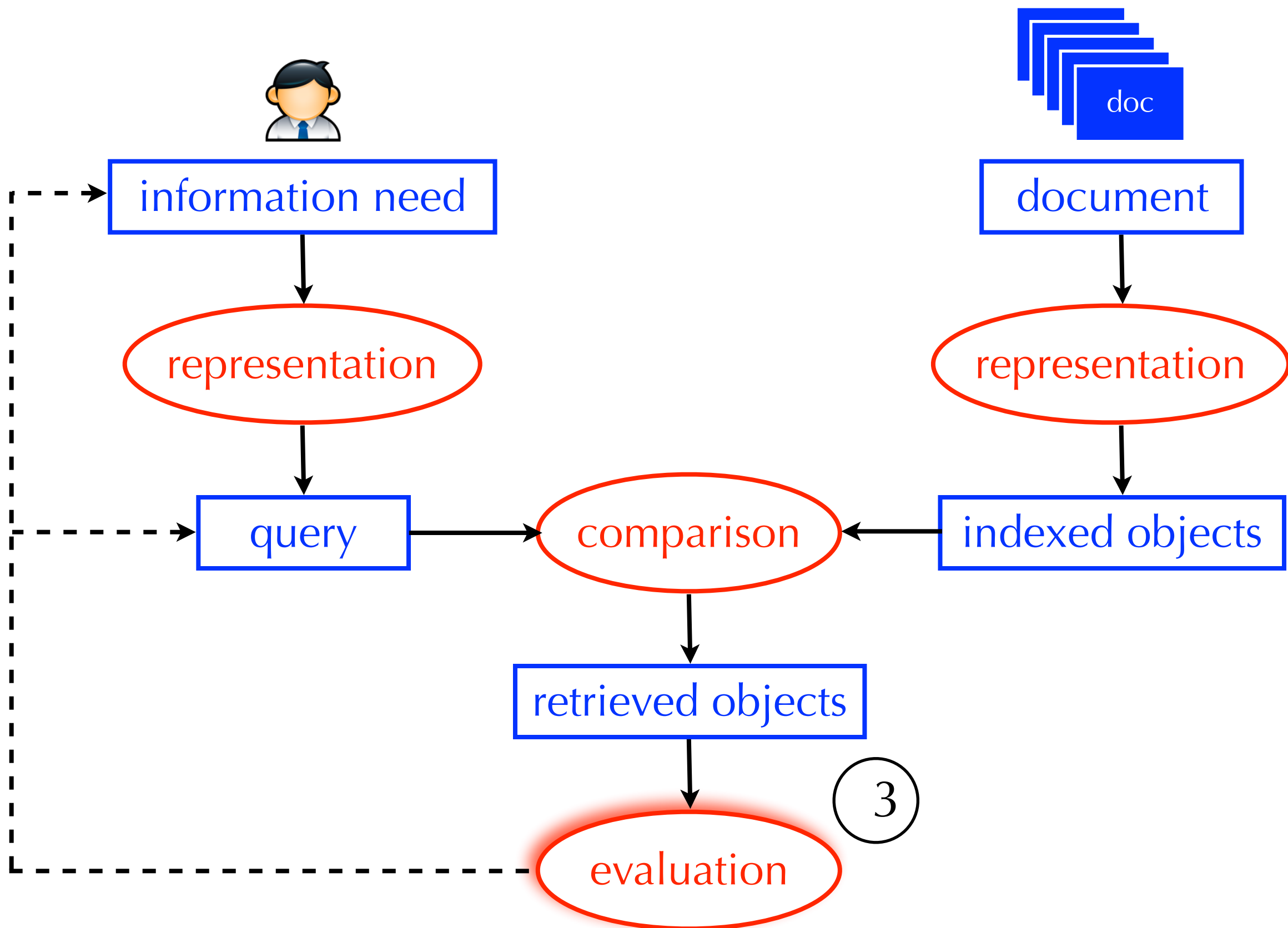
advantages

- Easy for the system (no ambiguity in the query)
 - ▶ the burden is on the user to formulate the right query
- The user gets **transparency** and **control**
 - ▶ lots of results → the query is too broad
 - ▶ no results → the query is too narrow
- Common strategy for finding the right balance:
 - ▶ if the query is too broad, add **AND** or **AND NOT** constraints
 - ▶ if the query is too narrow, add **OR** constraints

Information Need Representation



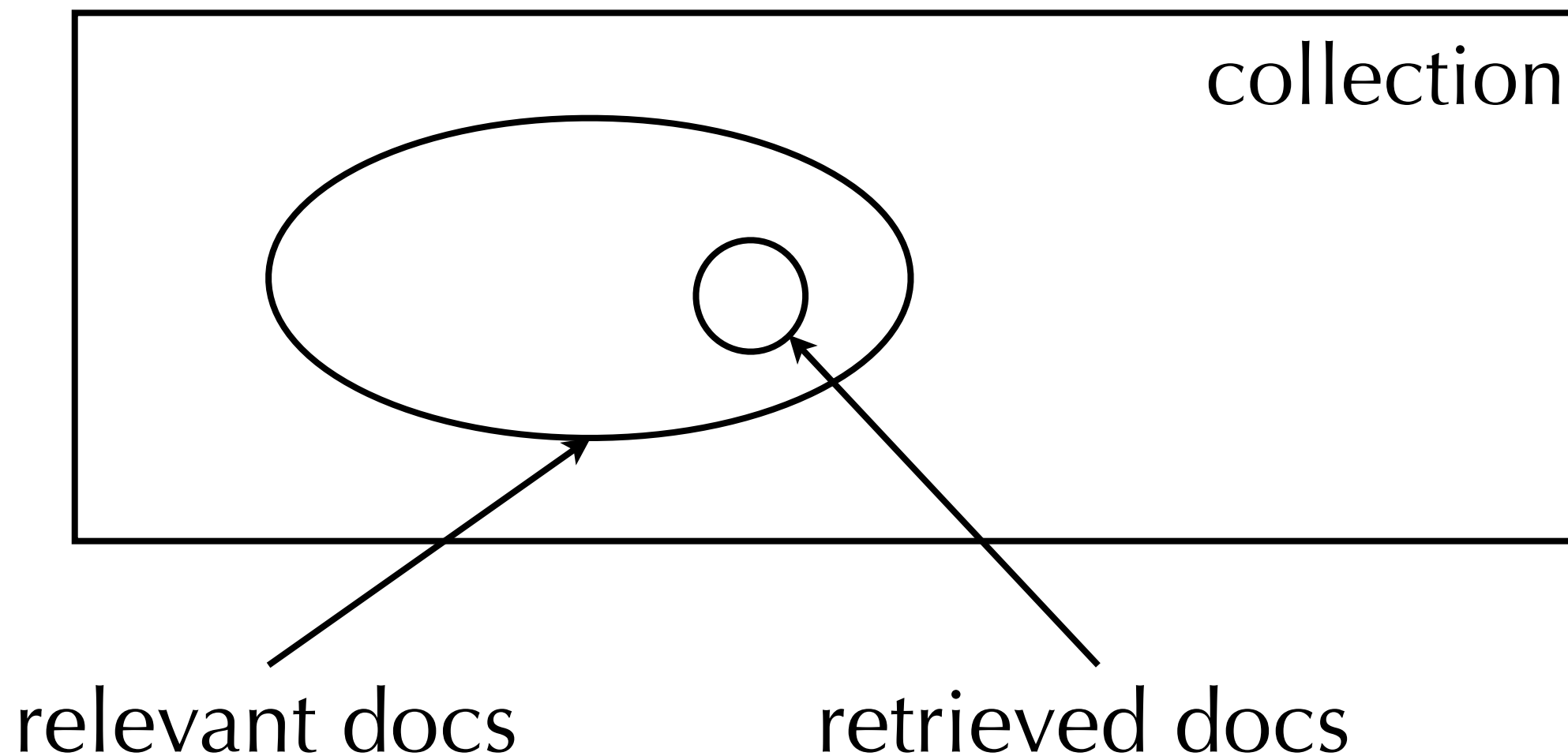
Evaluation



Boolean Retrieval

evaluation

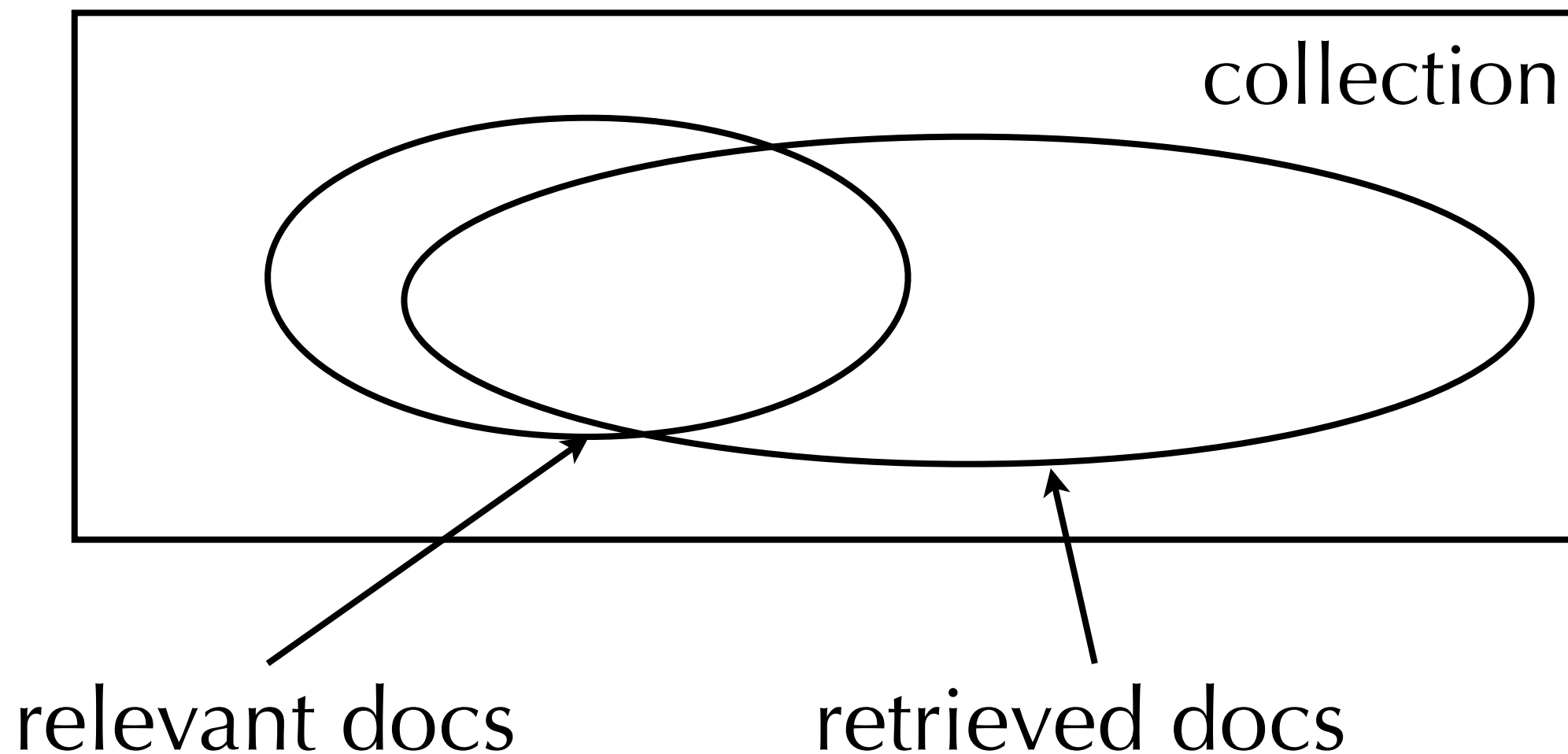
- **Assumption:** the user wants to find all the relevant documents and only the relevant documents
- If the query is too specific, it may retrieve relevant documents, but not enough



Boolean Retrieval

evaluation

- **Assumption:** the user wants to find all the relevant documents and only the relevant documents
- If the query is too broad, it may retrieve many relevant documents, but also many non-relevant ones



Boolean Retrieval

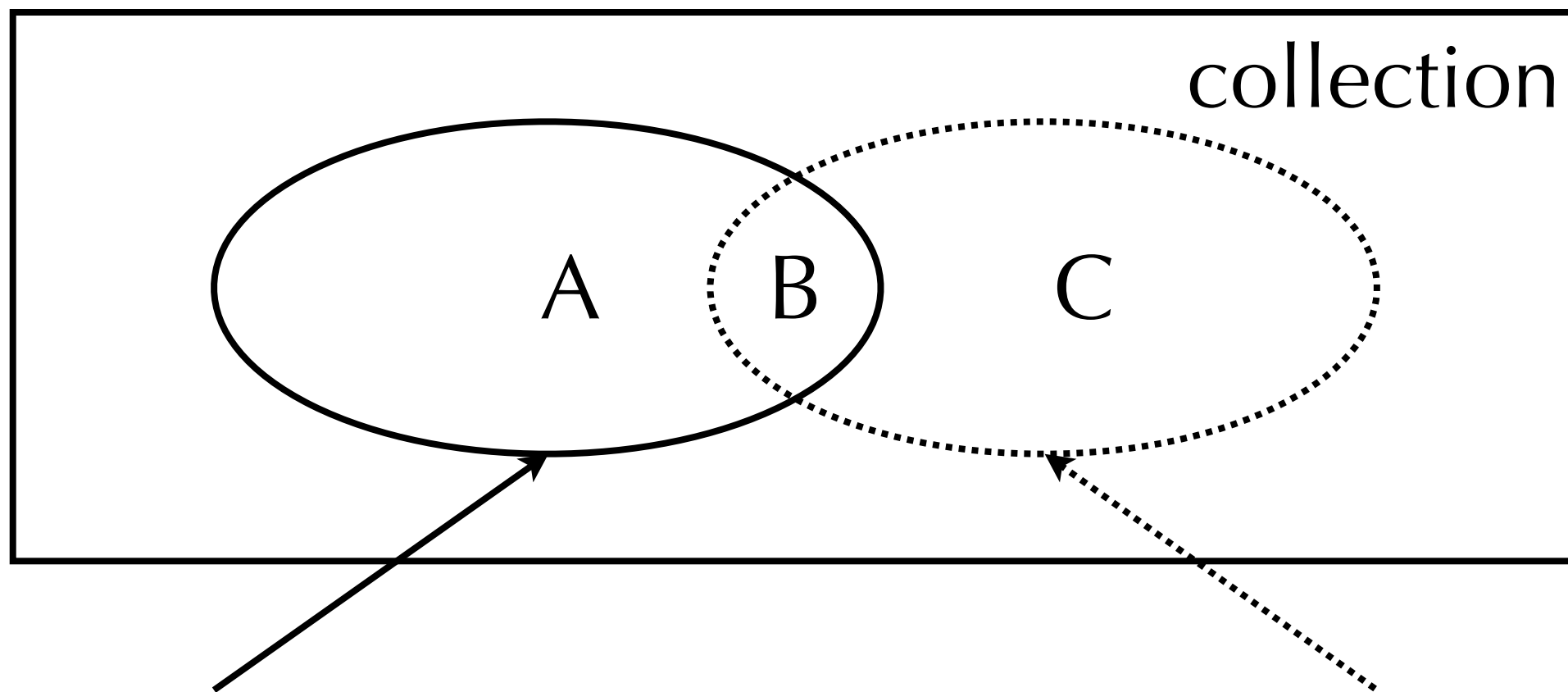
evaluation

- **Assumption:** the user wants to find all the relevant documents and only the relevant documents
- **Precision:** the percentage of retrieved documents that are relevant
- **Recall:** the percentage of relevant documents that are retrieved
- The goal of the user is to find the right balance between **precision** and **recall**
- These are important evaluation measures that we will see over and over again

Boolean Retrieval evaluation

- Precision = $\frac{?}{?}$

B = intersection of A and C



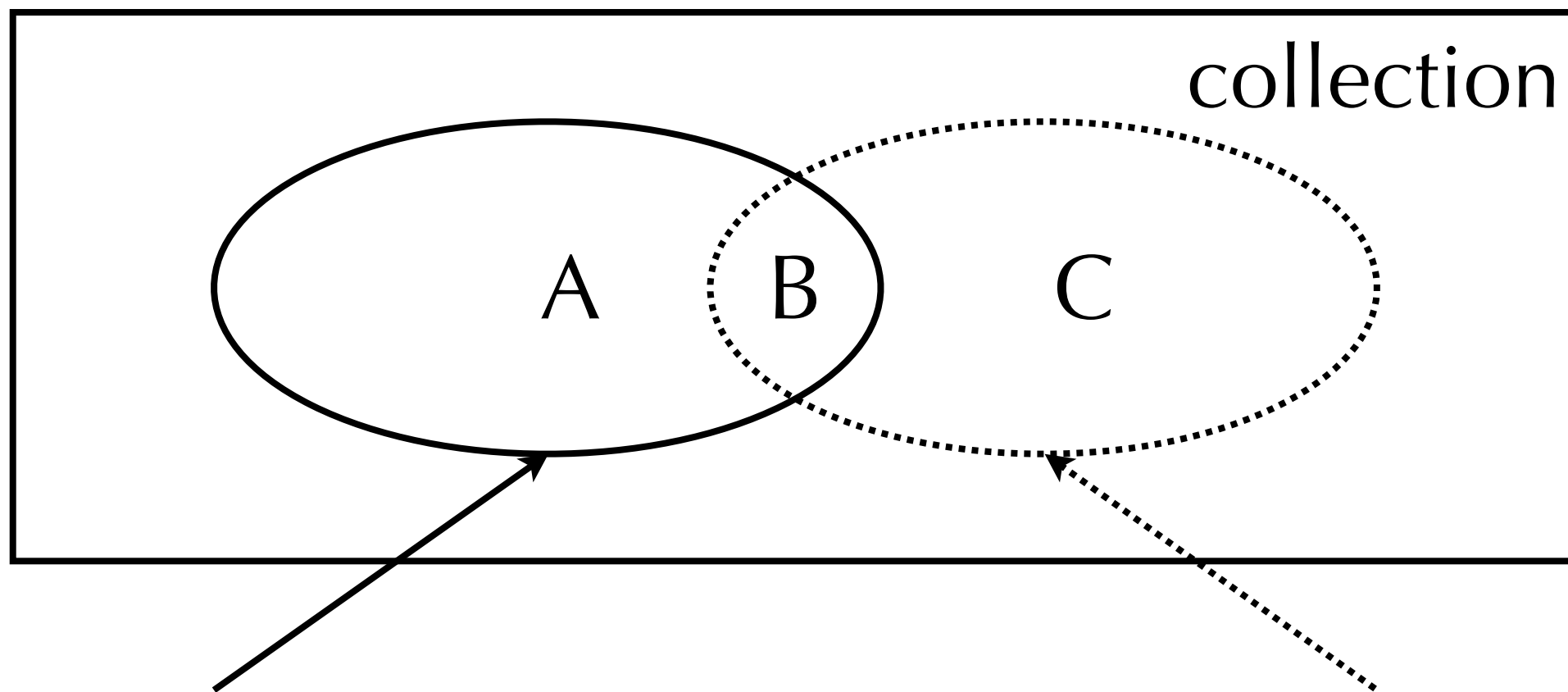
A = relevant docs

C = retrieved docs

Boolean Retrieval evaluation

- Precision = $\frac{|B|}{|C|}$

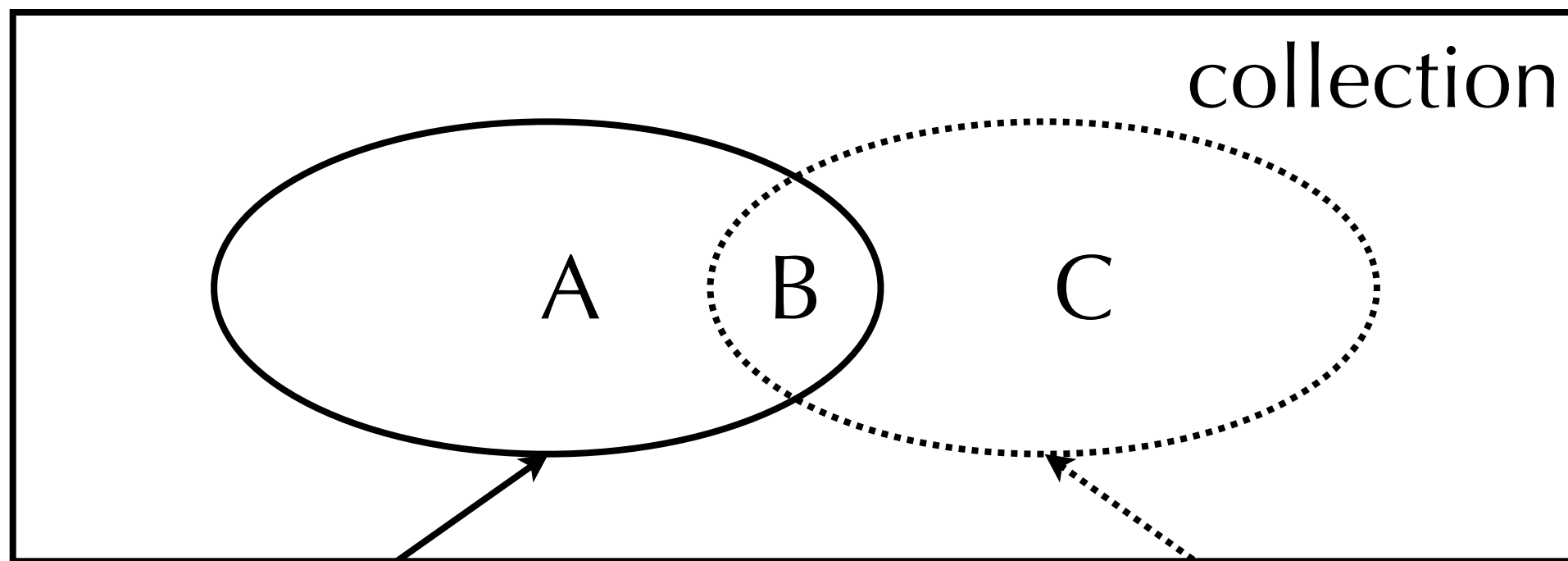
B = intersection of A and C



Boolean Retrieval evaluation

- Recall = $\frac{?}{?}$

B = intersection of A and C



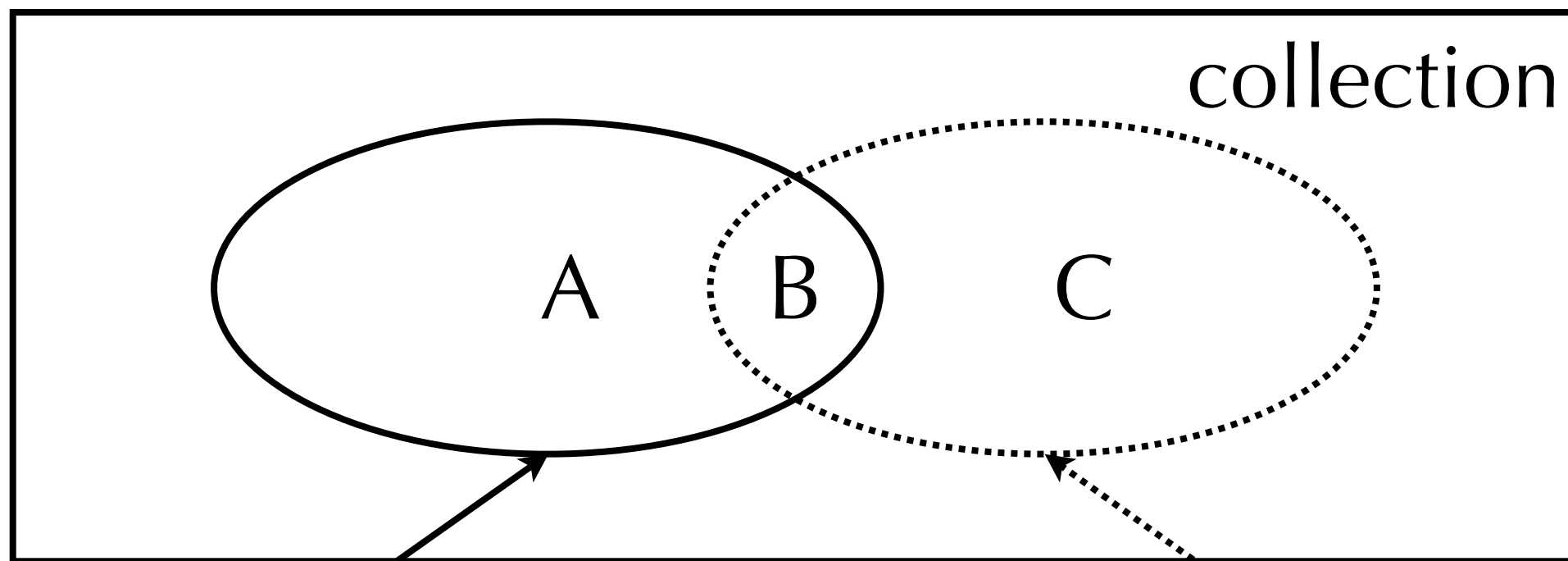
A = relevant docs

C = retrieved docs

Boolean Retrieval evaluation

- Recall = $\frac{|B|}{|A|}$

B = intersection of A and C



A = relevant docs

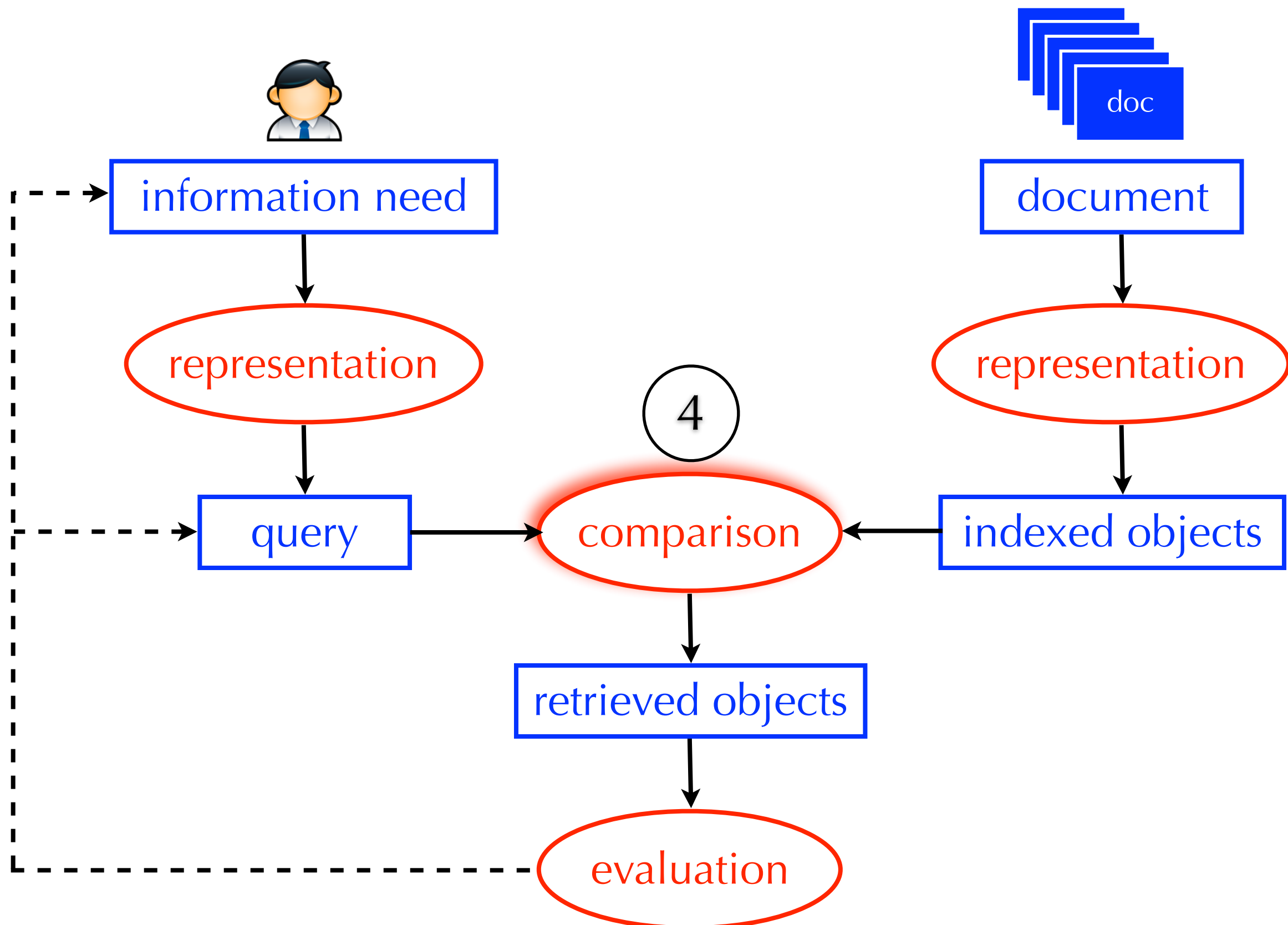
C = retrieved docs

Boolean Retrieval

evaluation

- If the query is too specific, **precision** may be high, but **recall** will probably be low
- If the query is too broad, **recall** may be high, but **precision** will probably be low
- Extreme cases:
 - ▶ a query that retrieves a single relevant document will have perfect **precision**, but low **recall** (unless only that one document is relevant)
 - ▶ a query that retrieves the entire collection will have perfect **recall**, but low **precision** (unless the entire collection is relevant)

Performing Retrieval



Most Basic View of a Search Engine

- A search engines does not scan each document to see if it satisfies the query
- That may be effective, but not efficient
- It uses an index to quickly locate the relevant documents
- **Index:** a list of concepts and pointers to documents that discuss them

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Indexing and Query Processing

- Next, we will see two types of indices and how they can be used to retrieve documents
- Bit-map index vs. variable-length inverted-list index
- In particular, we'll focus on how they can be used to evaluate boolean queries quickly
- Both produce the same output
- However, they go about it in different ways

Binary Full-text Representation

bitmap index

	<i>a</i>	<i>aardvark</i>	<i>abacus</i>	<i>abba</i>	<i>able</i>	...	<i>zoom</i>
<i>doc_1</i>	1	0	0	0	0	...	1
<i>doc_2</i>	0	0	0	0	1	...	1
::	::	::	::	::	::	...	0
<i>doc_m</i>	0	0	1	1	0	...	0

- 1 = the word appears in the document at least once
- 0 = the word does not appear in the document

Binary Full-text Representation

bitmap index

	<i>a</i>	<i>aardvark</i>	<i>abacus</i>	<i>abba</i>	<i>able</i>	...	<i>zoom</i>
<i>doc_1</i>	1	0	0	0	0	...	1
<i>doc_2</i>	0	0	0	0	1	...	1
::	::	::	::	::	::	...	0
<i>doc_m</i>	0	0	1	1	0	...	0

- 1 = the word appears in the document at least once
- 0 = the word does not appear in the document
- Does not represent word frequency, order, or location information

Binary Full-text Representation

bitmap index

	<i>a</i>	<i>aardvark</i>	<i>abacus</i>	<i>abba</i>	<i>able</i>	...	<i>zoom</i>
<i>doc_1</i>	1	0	0	0	0	...	1
<i>doc_2</i>	0	0	0	0	1	...	1
::	::	::	::	::	::	...	0
<i>doc_m</i>	0	0	1	1	0	...	0

- This type of document representation is known as a **bag of words** representation
- Term location information is lost
 - ▶ dog bites man = man bites dog
- Simplistic, but surprisingly effective for search

Binary Full-text Representation

bitmap index

	<i>a</i>	<i>aardvark</i>	<i>abacus</i>	<i>abba</i>	<i>able</i>	...	<i>zoom</i>
<i>doc_1</i>	1	0	0	0	0	...	1
<i>doc_2</i>	0	0	0	0	1	...	1
::	::	::	::	::	::	...	0
<i>doc_m</i>	0	0	1	1	0	...	0

- Every indexed term is associated with an inverted list
- **Inverted list:** marks the docs where the term appears at least once
- This type of inverted list is called a **bit-vector**
- In a bit-map index, all inverted lists (or bit-vectors) have the same number of elements

Processing a Boolean Query

- Query: *Jack* **AND** *Jill*

doc_1 Jack and Jill went up the hill
doc_2 To fetch a pail of water.
doc_3 Jack fell down and broke his crown,
doc_4 And Jill came tumbling after.
doc_5 Up Jack got, and home did trot,
doc_6 As fast as he could caper,
doc_7 To old Dame Dob, who patched his nob
doc_8 With vinegar and brown paper.

Processing a Boolean Query

- Query: *Jack* **AND** *Jill*

<i>docid</i>	<i>text</i>	<i>Jack</i>	<i>Jill</i>
<i>doc_1</i>	Jack and Jill went up the hill	1	1
<i>doc_2</i>	To fetch a pail of water.	0	0
<i>doc_3</i>	Jack fell down and broke his crown,	1	0
<i>doc_4</i>	And Jill came tumbling after.	0	1
<i>doc_5</i>	Up Jack got, and home did trot,	1	0
<i>doc_6</i>	As fast as he could caper,	0	0
<i>doc_7</i>	To old Dame Dob, who patched his nob	0	0
<i>doc_8</i>	With vinegar and brown paper.	0	0

Processing a Boolean Query

- Query: *Jack* **AND** *Jill*

	<i>Jack</i>	<i>Jill</i>	<i>Jack</i> AND <i>Jill</i>
<i>doc_1</i>	1	1	?
<i>doc_2</i>	0	0	?
<i>doc_3</i>	1	0	?
<i>doc_4</i>	0	1	?
<i>doc_5</i>	1	0	?
<i>doc_6</i>	0	0	?
<i>doc_7</i>	0	0	?
<i>doc_8</i>	0	0	?

Processing a Boolean Query

- Query: *Jack* **AND** *Jill*

	<i>Jack</i>	<i>Jill</i>	<i>Jack</i> AND <i>Jill</i>
<i>doc_1</i>	1	1	1
<i>doc_2</i>	0	0	0
<i>doc_3</i>	1	0	0
<i>doc_4</i>	0	1	0
<i>doc_5</i>	1	0	0
<i>doc_6</i>	0	0	0
<i>doc_7</i>	0	0	0
<i>doc_8</i>	0	0	0

Processing a Boolean Query

- Query: *Jack* OR *Jill*

<i>docid</i>	<i>text</i>	<i>Jack</i>	<i>Jill</i>
<i>doc_1</i>	Jack and Jill went up the hill	1	1
<i>doc_2</i>	To fetch a pail of water.	0	0
<i>doc_3</i>	Jack fell down and broke his crown,	1	0
<i>doc_4</i>	And Jill came tumbling after.	0	1
<i>doc_5</i>	Up Jack got, and home did trot,	1	0
<i>doc_6</i>	As fast as he could caper,	0	0
<i>doc_7</i>	To old Dame Dob, who patched his nob	0	0
<i>doc_8</i>	With vinegar and brown paper.	0	0

Processing a Boolean Query

- Query: *Jack* OR *Jill*

	<i>Jack</i>	<i>Jill</i>	<i>Jack</i> OR <i>Jill</i>
<i>doc_1</i>	1	1	?
<i>doc_2</i>	0	0	?
<i>doc_3</i>	1	0	?
<i>doc_4</i>	0	1	?
<i>doc_5</i>	1	0	?
<i>doc_6</i>	0	0	?
<i>doc_7</i>	0	0	?
<i>doc_8</i>	0	0	?

Processing a Boolean Query

- Query: *Jack* **OR** *Jill*

	<i>Jack</i>	<i>Jill</i>	<i>Jack</i> OR <i>Jill</i>
<i>doc_1</i>	1	1	1
<i>doc_2</i>	0	0	0
<i>doc_3</i>	1	0	1
<i>doc_4</i>	0	1	1
<i>doc_5</i>	1	0	1
<i>doc_6</i>	0	0	0
<i>doc_7</i>	0	0	0
<i>doc_8</i>	0	0	0

Processing a Boolean Query

- Query: *Jack* **AND** (*up* **OR** *down*)

	<i>up</i>	<i>down</i>	<i>up</i> OR <i>down</i>	<i>Jack</i>	<i>Jack</i> AND (<i>up</i> OR <i>down</i>)
<i>doc_1</i>	1	0	?	1	?
<i>doc_2</i>	0	0	?	0	?
<i>doc_3</i>	0	1	?	1	?
<i>doc_4</i>	0	0	?	0	?
<i>doc_5</i>	1	0	?	1	?
<i>doc_6</i>	0	0	?	0	?
<i>doc_7</i>	0	0	?	0	?
<i>doc_8</i>	0	0	?	0	?

Processing a Boolean Query

- Query: *Jack* **AND** (*up* **OR** *down*)

	<i>up</i>	<i>down</i>	<i>up</i> OR <i>down</i>	<i>Jack</i>	<i>Jack</i> AND (<i>up</i> OR <i>down</i>)
<i>doc_1</i>	1	0	1	1	?
<i>doc_2</i>	0	0	0	0	?
<i>doc_3</i>	0	1	1	1	?
<i>doc_4</i>	0	0	0	0	?
<i>doc_5</i>	1	0	1	1	?
<i>doc_6</i>	0	0	0	0	?
<i>doc_7</i>	0	0	0	0	?
<i>doc_8</i>	0	0	0	0	?

Processing a Boolean Query

- Query: *Jack* **AND** (*up* **OR** *down*)

	<i>up</i>	<i>down</i>	<i>up</i> OR <i>down</i>	<i>Jack</i>	<i>Jack</i> AND (<i>up</i> OR <i>down</i>)
<i>doc_1</i>	1	0	1	1	1
<i>doc_2</i>	0	0	0	0	0
<i>doc_3</i>	0	1	1	1	1
<i>doc_4</i>	0	0	0	0	0
<i>doc_5</i>	1	0	1	1	1
<i>doc_6</i>	0	0	0	0	0
<i>doc_7</i>	0	0	0	0	0
<i>doc_8</i>	0	0	0	0	0

Processing a Boolean Query

- Query: *Jack* AND NOT *Jill*

	<i>Jack</i>	<i>Jill</i>	<i>Jack</i> AND NOT <i>Jill</i>
<i>doc_1</i>	1	1	
<i>doc_2</i>	0	0	
<i>doc_3</i>	1	0	
<i>doc_4</i>	0	1	
<i>doc_5</i>	1	0	
<i>doc_6</i>	0	0	
<i>doc_7</i>	0	0	
<i>doc_8</i>	0	0	

Processing a Boolean Query

- Query: *Jack* AND NOT *Jill*

	<i>Jack</i>	<i>Jill</i>	NOT <i>Jill</i>	<i>Jack</i> AND NOT <i>Jill</i>
<i>doc_1</i>	1	1	?	?
<i>doc_2</i>	0	0	?	?
<i>doc_3</i>	1	0	?	?
<i>doc_4</i>	0	1	?	?
<i>doc_5</i>	1	0	?	?
<i>doc_6</i>	0	0	?	?
<i>doc_7</i>	0	0	?	?
<i>doc_8</i>	0	0	?	?

Processing a Boolean Query

- Query: *Jack* AND NOT *Jill*

	<i>Jack</i>	<i>Jill</i>	NOT <i>Jill</i>	<i>Jack</i> AND NOT <i>Jill</i>
<i>doc_1</i>	1	1	0	?
<i>doc_2</i>	0	0	1	?
<i>doc_3</i>	1	0	1	?
<i>doc_4</i>	0	1	0	?
<i>doc_5</i>	1	0	1	?
<i>doc_6</i>	0	0	1	?
<i>doc_7</i>	0	0	1	?
<i>doc_8</i>	0	0	1	?

Processing a Boolean Query

- Query: *Jack* AND NOT *Jill*

	<i>Jack</i>	<i>Jill</i>	NOT <i>Jill</i>	<i>Jack</i> AND NOT <i>Jill</i>
<i>doc_1</i>	1	1	0	0
<i>doc_2</i>	0	0	1	0
<i>doc_3</i>	1	0	1	1
<i>doc_4</i>	0	1	0	0
<i>doc_5</i>	1	0	1	1
<i>doc_6</i>	0	0	1	0
<i>doc_7</i>	0	0	1	0
<i>doc_8</i>	0	0	1	0

The Binary Full-text Representation

	<i>a</i>	<i>aardvark</i>	<i>abacus</i>	<i>abba</i>	<i>able</i>	...	<i>zoom</i>
<i>doc_1</i>	1	0	0	0	0	...	1
<i>doc_2</i>	0	0	0	0	1	...	1
::	::	::	::	::	::	...	0
<i>doc_m</i>	0	0	1	1	0	...	0

- These are fixed-length inverted lists, each of size m (the number of documents in the collection)
- Are these inverted lists efficient in terms of storage?

Statistical Properties of Text

sneak preview!

- IMDB collection (movies, artist/role, plot descriptions)
 - ▶ number of documents: 230,721
 - ▶ number of term occurrences: 36,989,629
 - ▶ number of unique terms: ????
- Term Statistics
 - ▶ Most terms occur very infrequently
 - ▶ ??? of all terms occur only once
 - ▶ ??? occur 5 times or less
 - ▶ ??? occur 10 times or less
 - ▶ Only ??? occur 50 times or more

Statistical Properties of Text

sneak preview!

- IMDB collection (movies, artist/role, plot descriptions)
 - ▶ number of documents: 230,721
 - ▶ number of term occurrences: 36,989,629
 - ▶ number of unique terms: 424,035
- Term Statistics
 - ▶ Most terms occur very infrequently
 - ▶ ??? of all terms occur only once
 - ▶ ??? occur 5 times or less
 - ▶ ??? occur 10 times or less
 - ▶ Only ??? occur 50 times or more

Statistical Properties of Text

sneak preview!

- IMDB collection (movies, artist/role, plot descriptions)
 - ▶ number of documents: 230,721
 - ▶ number of term occurrences: 36,989,629
 - ▶ number of unique terms: 424,035
- Term Statistics
 - ▶ Most terms occur very infrequently
 - ▶ 44% of all terms occur only once
 - ▶ 77% occur 5 times or less
 - ▶ 85% occur 10 times or less
 - ▶ Only 6% occur 50 times or more

Sparse Representation of an Inverted List

- Most terms appear in only a few documents
- Most bit-vectors have many 0's and only a few 1's
- A bitmap index is very inefficient
- **Alternative:** represent only the 1's:
 - ▶ aardvark: 00101011....
 - ▶ aardvark: $df = 18; 3, 5, 7, 8, \dots$
- df = number of documents in which the term appears at least once
- Each document has a unique identifier (docid)

Inverted Index Full-text Representation

<i>a</i>	<i>aardvark</i>	<i>abacus</i>	<i>abba</i>	<i>able</i>	...	<i>zoom</i>
<i>df=3421</i>	<i>df=22</i>	<i>df=19</i>	<i>df=2</i>	<i>df=44</i>		<i>df=1</i>
1	33	2	33	66		54
33	56	10	150	134		
45	86	15		176		
::	::	::		::		
1022	1011	231		432		

- Variable-length inverted lists
- Each document has a unique identifier (**docid**)
- Why are the inverted lists sorted by docid?
- Why do we store the *df*'s in the index?

Merging (Variable-Length) Inverted Lists AND

- Query: Jack **AND** and

1. If docids are equal, add docid to results and increment both pointers

2. If docids are not equal, increment pointer with lowest docid

3. Repeat until (1) end of one list and (2) docid from other list is greater

Jack	and	Jack AND and
df=3	df=5	count=1
1	1	1
3	3	
5	4	
	5	
	8	

Merging (Variable-Length) Inverted Lists AND

- Query: Jack **AND** and

1. If docids are equal, add docid to results and increment both pointers

2. If docids are not equal, increment pointer with lowest docid

3. Repeat until (1) end of one list and (2) docid from other list is greater

Jack	and	Jack AND and
df=3	df=5	count=2
1	1	1
3	3	3
5	4	
	5	
	8	

Merging (Variable-Length) Inverted Lists AND

- Query: Jack **AND** and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, increment pointer with lowest docid
3. Repeat until (1) end of one list and (2) docid from other list is greater

Jack	and	Jack AND and
df=3	df=5	count=2
1	1	1
3	3	3
5	4	
	5	
	8	

Merging (Variable-Length) Inverted Lists AND

- Query: Jack **AND** and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, increment pointer with lowest docid
3. Repeat until (1) end of one list and (2) docid from other list is greater

Jack	and	Jack AND and
df=3	df=5	count=3
1	1	1
3	3	3
5	4	5
	5	
	8	

Merging (Variable-Length) Inverted Lists AND

- Query: Jack **AND** and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, increment pointer with lowest docid
3. Repeat until (1) end of one list and (2) docid from other list is greater

Jack	and	Jack AND and
df=3	df=5	count=3
1	1	1
3	3	3
5	4	5
	5	
	8	

stop!

Merging (Variable-Length) Inverted Lists AND

- Query: Jack **AND** and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, increment pointer with lowest docid
3. Repeat until (1) end of one list and (2) docid from other list is greater

Jack	and	Jack AND and
df=3	df=5	count=3
1	1	1
3	3	3
5	4	5
	5	
	8	
	10	
	35	

If the inverted list for “and” was longer, would it make sense to continue? Why or why not?

Merging (Variable-Length) Inverted Lists AND

- Query: Jack **AND** and

	Jack	and	Jack AND and
1. If docids are equal, add docid to results increment both pointers		=5	count=3
2. If docids are not equal, increment pointer to lowest docid		1 3 4 5 8	1 3 5
3. Repeat until (1) end of one list <u>and</u> (2) docid from other list is greater		10 35	

This is why the
inverted lists are
sorted in ascending
order of docid!

If the inverted list for “and” was longer, would it make sense to continue? Why or why not?

Merging (Variable-Length) Inverted Lists OR

- Query: Jack OR and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, add lowest docid and increment its pointer
3. Repeat until end of both lists

Jack	and	Jack OR and
df=3	df=5	count=5
1	1	1
3	3	3
5	4	4
	5	5
	8	8

Merging (Variable-Length) Inverted Lists OR

- Query: Jack OR and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, add lowest docid and increment its pointer
3. Repeat until end of both lists

Jack	and	Jack OR and
df=3	df=5	count=5
1	1	1
3	3	
5	4	
	5	
	8	

Merging (Variable-Length) Inverted Lists

OR

- Query: Jack **OR** and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, add lowest docid and increment its pointer
3. Repeat until end of both lists

Jack	and	Jack OR and
df=3	df=5	count=5
1	1	1
3	3	3
5	4	
	5	
	8	

Merging (Variable-Length) Inverted Lists

OR

- Query: Jack **OR** and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, add lowest docid and increment its pointer
3. Repeat until end of both lists

Jack	and	Jack OR and
df=3	df=5	count=5
1	1	1
3	3	3
5	4	4
	5	
	8	

Merging (Variable-Length) Inverted Lists OR

- Query: Jack OR and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, add lowest docid and increment its pointer
3. Repeat until end of both lists

Jack	and	Jack OR and
df=3	df=5	count=5
1	1	1
3	3	3
5	4	4
	5	5
	8	

Merging (Variable-Length) Inverted Lists OR

- Query: Jack OR and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, add lowest docid and increment its pointer
3. Repeat until end of both lists

Jack	and	Jack OR and
df=3	df=5	count=5
1	1	1
3	3	3
5	4	4
	5	5
	8	8

stop!

Merging (Variable-Length) Inverted Lists

OR

- Query: Jack **OR** and

1. If docids are equal, add docid to results and increment both pointers
2. If docids are not equal, add lowest docid and increment its pointer
3. Repeat until end of both lists

Jack	and	Jack OR and
df=3	df=5	count=5
1	1	1
3	3	3
5	4	4
	5	5
	8	8

- Which is more expensive (on average) **AND** or **OR**?

Merging (Variable-Length) Inverted Lists

- In some cases, the search engine has a choice in the order of operations
- Query: Abraham AND Lincoln AND President
 - ▶ option 1: (Abraham AND Lincoln) AND President
 - ▶ option 2: Abraham AND (Lincoln AND President)
 - ▶ option 3: (Abraham AND President) AND Lincoln
- Which is probably the least effective order of operations?

Merging (Variable-Length) Inverted Lists

- Which is probably the most effective order of operations?

<i>president</i>	<i>abraham</i>	<i>lincoln</i>
<i>df=302</i>	<i>df=45</i>	<i>df=5</i>
XX	XX	XX
XX	XX	XX
XX	XX	XX
XX	XX	XX
XX	XX	XX
::	::	
XX	XX	

Retrieval Model 1: Unranked Boolean

- Retrieves the set of documents that match the boolean query (an “exact-match” retrieval model)
- Returns results in no particular order (ordered by date?)
- This is problematic with large collections
 - ▶ requires complex queries to reduce the result set to a manageable size
- Can we do better?

Retrieval Model 2: Ranked Boolean

<i>University</i>	<i>North</i>	<i>Carolina</i>	<i>UNC</i>
<i>df=6</i>	<i>df=4</i>	<i>df=3</i>	<i>df=5</i>
1, 4	1, 4	1, 4	1, 4
10, 1	10, 5	10, 5	10, 1
15, 2	16, 1	16, 1	16, 4
16, 1	68, 1		33, 2
33, 5			56, 10
67, 7			

- *docid = document identifier*
- *tf = term frequency (# of times the term appears in the document)*

Retrieval Model 2: Ranked Boolean

- At each step, keep a list of documents that match the query and their scores (a.k.a. a “priority queue”)
- Score computation:
 - ▶ A **AND** B: adjust the document score based on the **minimum** frequency/score associated with expression A and expression B
 - ▶ A **OR** B: adjust the document score based on the **sum** of frequencies/scores associated with expression A and expression B

Retrieval Model 2: Ranked Boolean

- Query: (University **AND** North **AND** Carolina) **OR** UNC

<i>University</i>	<i>North</i>	<i>Carolina</i>	<i>UNC</i>
<i>df=6</i>	<i>df=4</i>	<i>df=3</i>	<i>df=5</i>
1, 4	1, 4	1, 4	1, 4
10, 1	10, 5	10, 5	10, 1
15, 2	16, 1	16, 1	16, 4
16, 1	68, 1		33, 2
33, 5			56, 10
68, 7			

- AND** → min
- OR** → sum

Retrieval Model 2: Ranked Boolean

- Query: (University AND North AND Carolina) OR UNC

<i>University</i>	<i>North</i>	<i>Carolina</i>	<i>Result_1</i>
<i>df=6</i>	<i>df=4</i>	<i>df=3</i>	<i>count=??</i>
1, 4	1, 4	1, 4	
10, 1	10, 5	10, 5	
15, 2	16, 1	16, 1	
16, 1	68, 1		
33, 5			
68, 7			

- AND → min
- OR → sum

Retrieval Model 2: Ranked Boolean

- Query: (University AND North AND Carolina) OR UNC

<i>University</i>	<i>North</i>	<i>Carolina</i>	<i>Result_1</i>
<i>df=6</i>	<i>df=4</i>	<i>df=3</i>	<i>count=3</i>
1, 4	1, 4	1, 4	1, 4
10, 1	10, 5	10, 5	10, 1
15, 2	16, 1	16, 1	16, 1
16, 1	68, 1		
33, 5			
68, 7			

- AND → min
- OR → sum

Retrieval Model 2: Ranked Boolean

- Query: (University AND North AND Carolina) OR UNC

<i>Result_1</i>	<i>UNC</i>	<i>Query</i>
<i>count=3</i>	<i>df=5</i>	<i>count=??</i>
1, 4	1, 4	
10, 1	10, 1	
16, 1	16, 4	
	33, 2	
	56, 10	

- AND → min
- OR → sum

Retrieval Model 2: Ranked Boolean

- Query: (University AND North AND Carolina) OR UNC

<i>Result_1</i>	<i>UNC</i>	<i>Query</i>
<i>count=3</i>	<i>df=5</i>	<i>count=5</i>
1, 4	1, 4	1, 8
10, 1	10, 1	10, 2
16, 1	16, 4	16, 5
	33, 2	33, 2
	56, 10	56, 10

- AND → min
- OR → sum

Retrieval Model 2: Ranked Boolean

- Query: (University AND North AND Carolina) OR UNC

<i>University</i>	<i>North</i>	<i>Carolina</i>	<i>UNC</i>	<i>Query</i>
<i>df=6</i>	<i>df=4</i>	<i>df=3</i>	<i>df=5</i>	<i>count=5</i>
1, 4	1, 4	1, 4	1, 4	1, 8
10, 1	10, 5	10, 5	10, 1	10, 2
15, 2	16, 1	16, 1	16, 4	16, 5
16, 1	68, 1		33, 2	33, 2
33, 5			56, 10	56, 10
68, 7				

- Conceptually, what do these document scores indicate?

Retrieval Model 2: Ranked Boolean

- Query: (University AND North AND Carolina) OR UNC

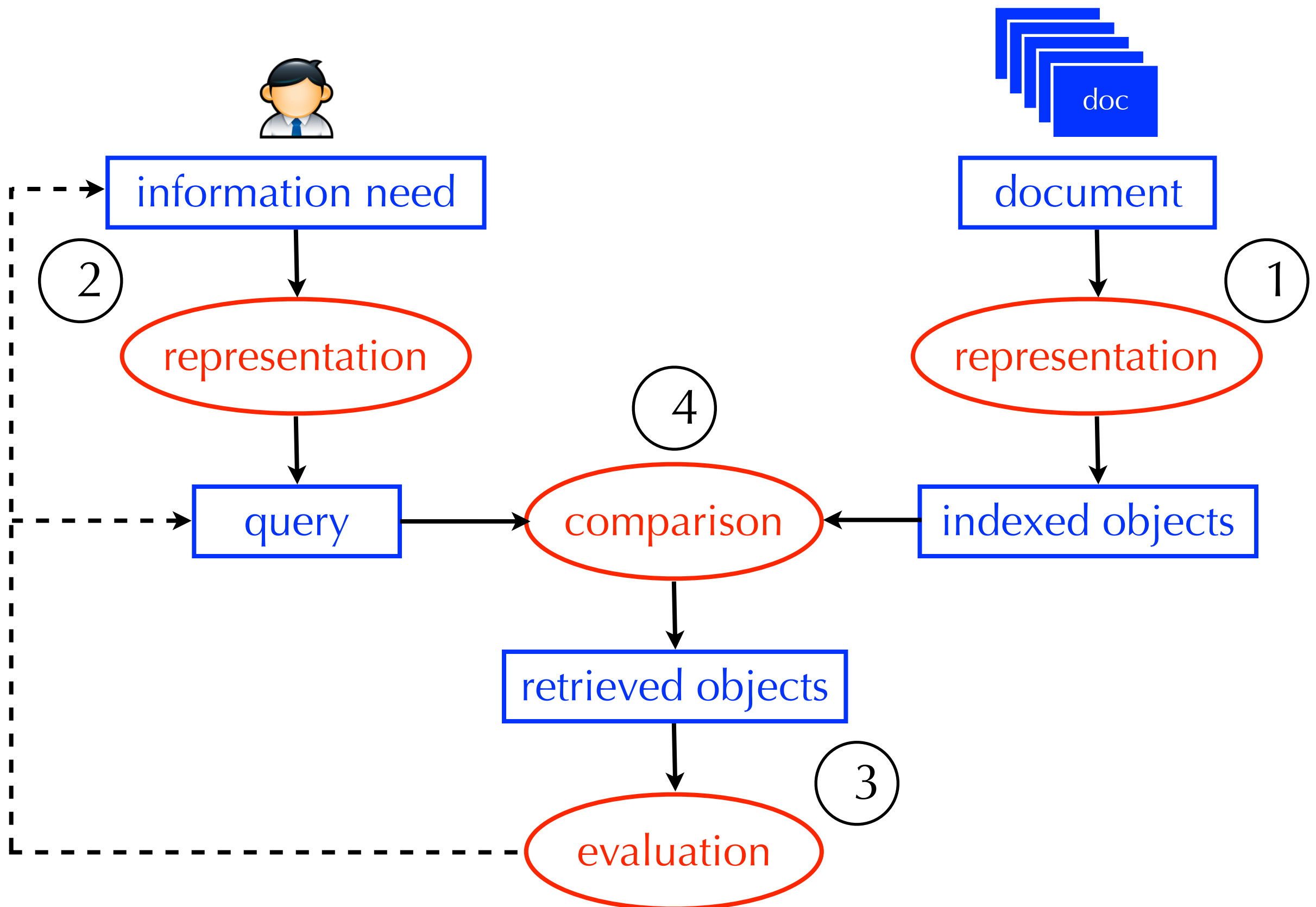
University	North	Carolina	UNC	Query
df=6	df=4	df=3	df=5	count=5
1, 4	1, 4	1, 4	1, 4	1, 8
10, 1	10, 5	10, 5	10, 1	10, 2
15, 2	16, 1	16, 1	16, 4	16, 5
16, 1	68, 1		33, 2	33, 2
33, 5			56, 10	56, 10
68, 7				

- The **scores** correspond to the number of ways in which the document redundantly satisfies the query

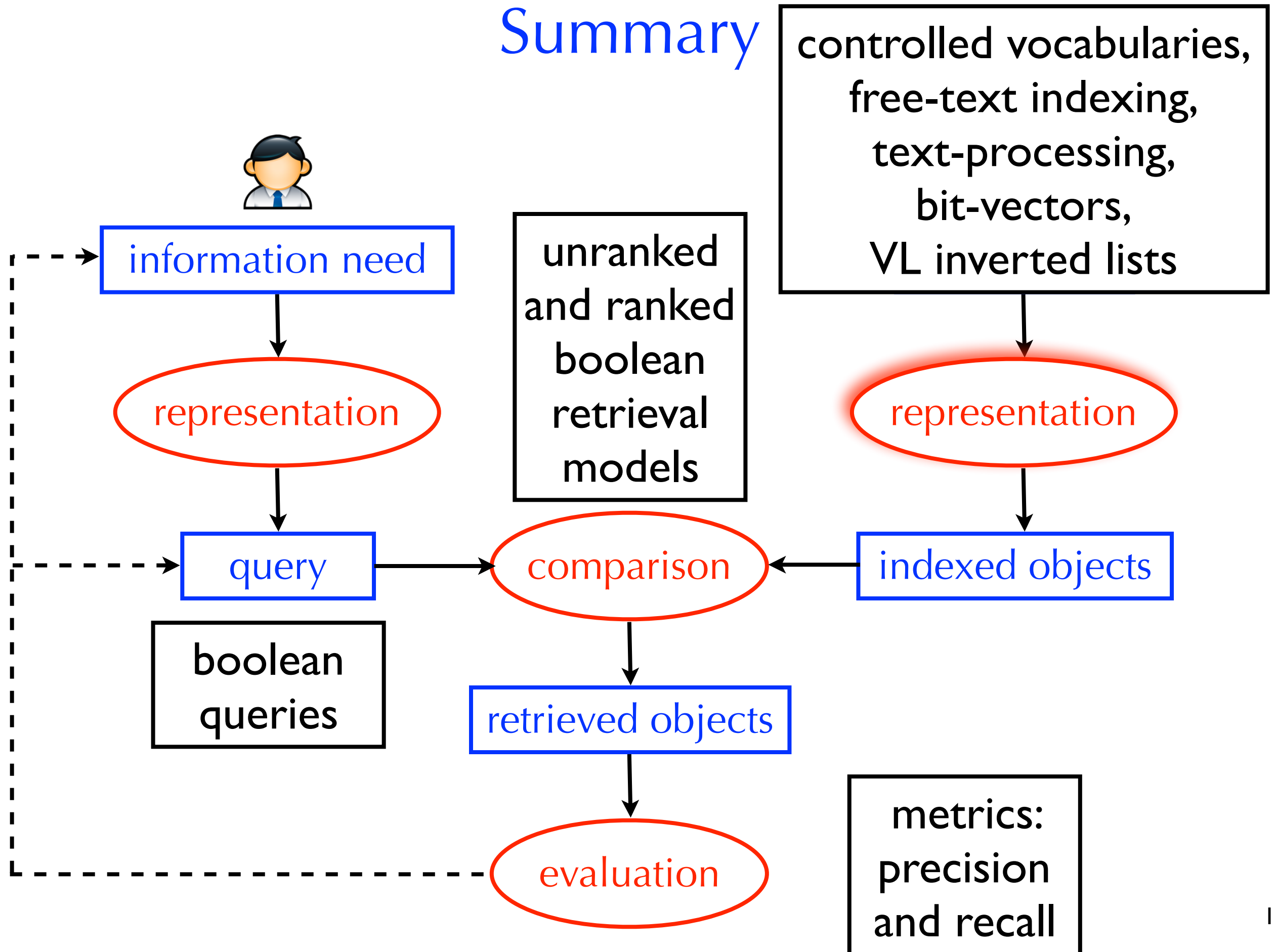
Retrieval Model 2: Ranked Boolean

- Advantages:
 - ▶ same as unranked boolean: efficient, predictable, easy to understand, works well when the user knows what to look for
 - ▶ the user may be able to find relevant documents quicker and may not need to examine the entire result set
- Disadvantages:
 - ▶ same as unranked boolean: works well when the user knows what to look for
 - ▶ difficult to balance precision and recall

Summary



Summary



Take Home Message

- Congratulations! Now, you know how a boolean search engine works
- How are indexes structured?
- How are boolean queries processed quickly?
- What are some time-saving hacks?
- How are boolean retrieval sets evaluated?
- How can we prioritize documents based on how much they satisfy the boolean constraints?