

Introduction to Information Retrieval

<http://informationretrieval.org>

IIR 10: XML Retrieval

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Overview

- 1 Introduction
- 2 Basic XML concepts
- 3 Challenges in XML IR
- 4 Vector space model for XML IR
- 5 Evaluation of XML IR

Outline

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IR and relational databases

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Some structured data sources containing text are best modeled as structured documents rather than relational data (**Structured retrieval**).

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Example

- Digital libraries: *give me a full-length article on fast fourier transforms*
- Patents: *give me patents whose claims mention RSA public key encryption and that cite US patent 4,405,829*
- Entity-tagged text: *give me articles about sightseeing tours of the Vatican and the Coliseum*

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Solution: adapt ranked retrieval to structured documents to address these problems.

Structured Retrieval

RDB search, Unstructured IR, Structured IR

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- structured IR \rightarrow XML IR
- also applicable to other types of markup (HTML, SGML, ...)

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- Each node of the tree is an XML element, written with an opening and closing XML tag (e.g. `<title...>`, `</title...>`)

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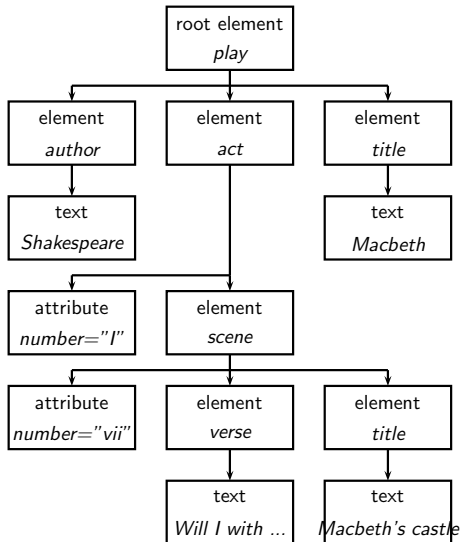
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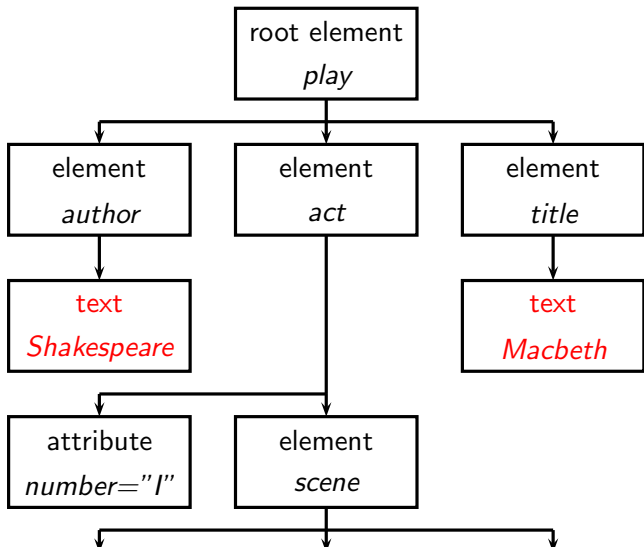
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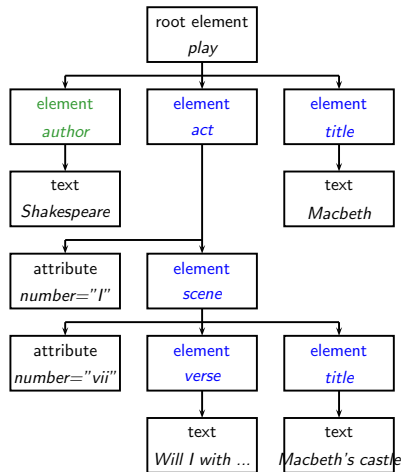
XML document

The **leaf nodes** consist of text



XML document

The *internal nodes* encode **document structure** or **metadata** functions



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 - Two standards for schemas for XML documents are: **XML DTD** (document type definition) and **XML Schema**.

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- Hard to implement this principle algorithmically. E.g. query: *title:Macbeth* can match both the title of the tragedy, *Macbeth*, and the title of Act I, Scene vii, *Macbeth's castle*.

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- Hard to implement this principle algorithmically. E.g. query: *title:Macbeth* can match both the title of the tragedy, *Macbeth*, and the title of Act I, Scene vii, *Macbeth's castle*.
 - But in this case, the title of the tragedy (higher node) is preferred.
 - Difficult to decide which level of the tree satisfies the query.

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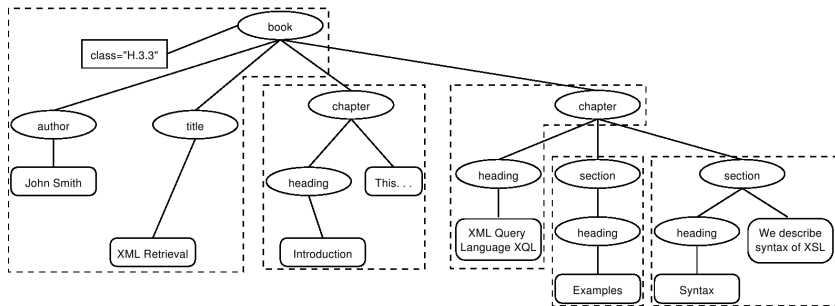
- In unstructured retrieval, usually straightforward: files on your desktop, email messages, web pages on the web etc.
- In structured retrieval, there are four main different approaches to defining the indexing unit.
 - 1 non-overlapping pseudodocuments
 - 2 top down
 - 3 bottom up
 - 4 all

XML indexing unit: approach 1

Group nodes into non-overlapping pseudodocuments.

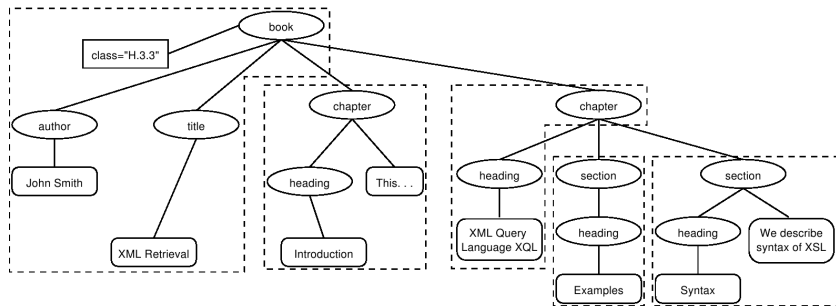
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Indexing units: books, chapters, sections, but **without overlap**.

Disadvantage: pseudodocuments may not make sense to the user because they are not coherent units.

XML indexing unit: approach 2

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- 1 start with one of the largest elements as the indexing unit, e.g. the *book* element in a collection of books
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Top down (2-stage process):

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This two-stage retrieval process often fails to return the best subelement because the relevance of a whole book is often not a good predictor of the relevance of small subelements within it.

XML indexing unit: approach 3

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Instead of retrieving large units and identifying subelements (top down), we can search all leaves, select the most relevant ones and then extend them to larger units in postprocessing.

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Instead of retrieving large units and identifying subelements (top down), we can search all leaves, select the most relevant ones and then extend them to larger units in postprocessing.

Similar problem as top down: the relevance of a leaf element is often not a good predictor of the relevance of elements it is contained in.

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Example

For the query *Macbeth's castle* we would return all of the *play*, *act*, *scene* and *title* elements on the path between the root node and *Macbeth's castle*. The leaf node would then occur 4 times in the result set: 1 directly and 3 as part of other elements.

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We call elements that are contained within each other **nested elements**. Returning redundant nested elements in a list of returned hits is not very user-friendly.

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In most of these approaches, result sets will still contain nested elements.

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Highlighting

- Gain 1: enables users to scan medium-sized elements (e.g., a section); thus, if the section and the paragraph both occur in the results list, it is sufficient to show the section.
- Gain 2: paragraphs are presented in-context (i.e., their embedding section). This context may be helpful in interpreting the paragraph.

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Solution: compute idf for **XML-context term pairs**.

- sparse data problems (many XML-context pairs occur too rarely to reliably estimate df)
- compromise: consider the parent node x of the term and not the rest of the path from the root to x to distinguish contexts.

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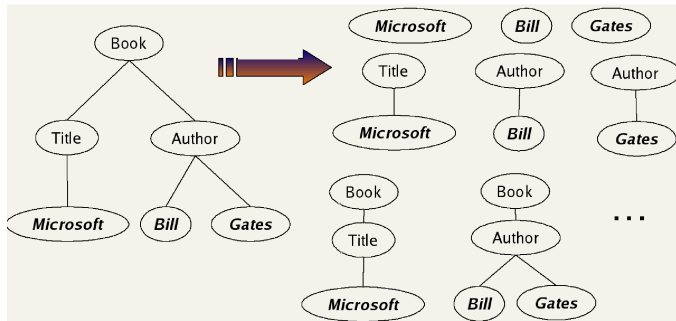
Main idea: lexicalised subtrees

Aim: to have each dimension of the vector space encode a word together with its position within the XML tree.

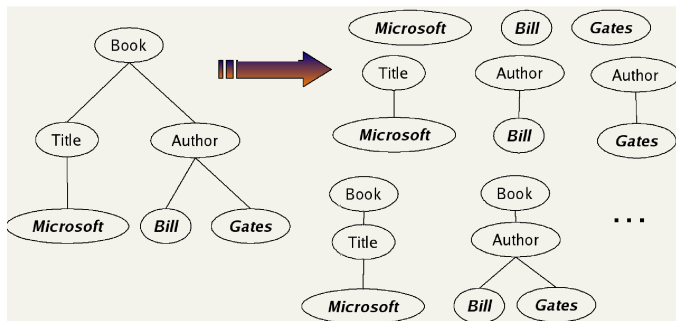
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How: Map XML documents to lexicalised subtrees.

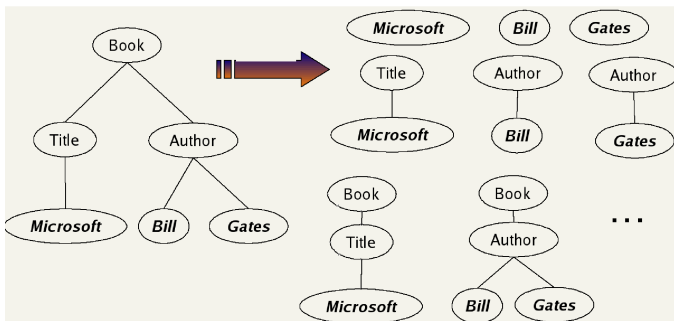


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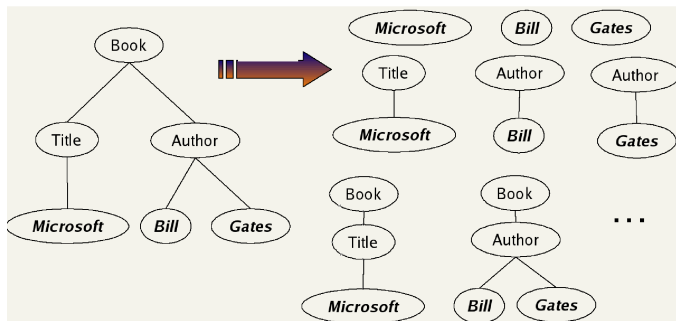
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- 2 Define the dimensions of the vector space to be lexicalized subtrees of documents – subtrees that contain at least one vocabulary term.



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Vector space formalism in unstructured VS. structured IR

The main difference is that the dimensions of vector space in unstructured retrieval are vocabulary terms whereas they are lexicalized subtrees in XML retrieval.

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Compromise: index all paths that end in a single vocabulary term, in other words, all XML-context term pairs. We call such an XML-context term pair a **structural term** and denote it by $\langle c, t \rangle$: a pair of XML-context c and vocabulary term t .

Context resemblance

A simple measure of the similarity of a path c_q in a query and a path c_d in a document is the following *context resemblance* function CR :

$$\text{CR}(c_q, c_d) = \begin{cases} \frac{1+|c_q|}{1+|c_d|} & \text{if } c_q \text{ matches } c_d \\ 0 & \text{if } c_q \text{ does not match } c_d \end{cases} \quad (1)$$

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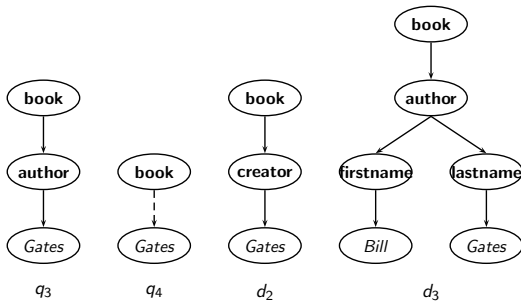
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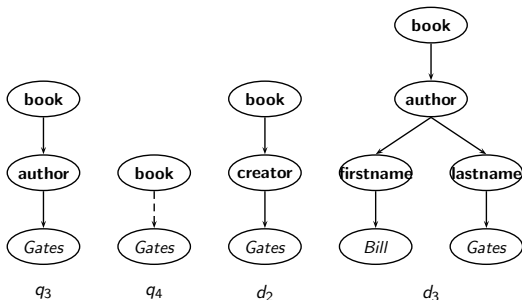
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c_q matches c_d iff we can transform c_q into c_d by inserting additional nodes.

Context resemblance example



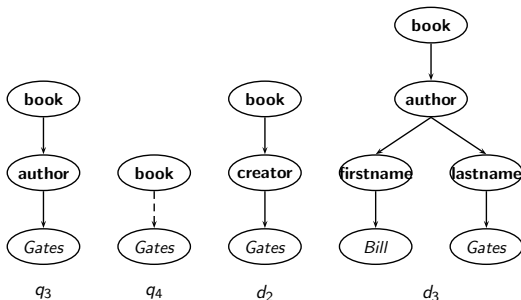
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$$\text{CR}(c_{q_4}, c_{d_2}) = 3/4 = 0.75.$$

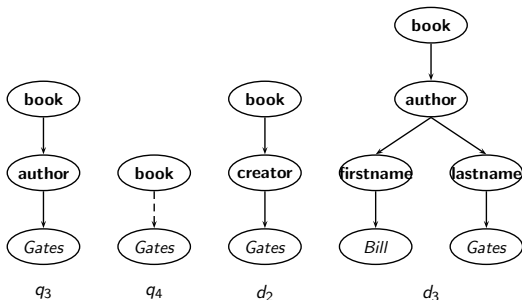
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$$\text{CR}(c_q, c_d) = \begin{cases} \frac{1+|c_q|}{1+|c_d|} & \text{if } c_q \text{ matches } c_d \\ 0 & \text{if } c_q \text{ does not match } c_d \end{cases}$$

$\text{CR}(c_{q_4}, c_{d_2}) = 3/4 = 0.75$. The value of $\text{CR}(c_q, c_d)$ is 1.0 if q and d are identical.

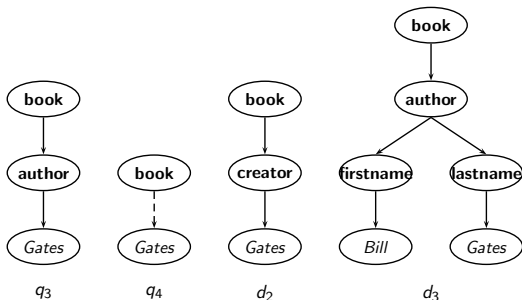
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$$\text{CR}(c_{q_4}, c_{d_3}) = ?$$

$$\text{CR}(c_{q_4}, c_{d_3}) = 3/5 = 0.6.$$

Document similarity measure

The final score for a document is computed as a variant of the cosine measure, which we call SIMNOMERGE.

$\text{SIMNOMERGE}(q, d) =$

$$\sum_{c_k \in B} \sum_{c_l \in B} \text{CR}(c_k, c_l) \sum_{t \in V} \text{weight}(q, t, c_k) \frac{\text{weight}(d, t, c_l)}{\sqrt{\sum_{c \in B, t \in V} \text{weight}^2(d, t, c)}}$$

- V is the vocabulary of non-structural terms
- B is the set of all XML contexts
- $\text{weight}(q, t, c)$, $\text{weight}(d, t, c)$ are the weights of term t in XML context c in query q and document d , resp. (standard weighting e.g. $\text{idf}_t \cdot \text{wf}_{t,d}$, where idf_t depends on which elements we use to compute df_t .)

$\text{SIMNOMERGE}(q, d)$ is not a true cosine measure since its value can be larger than 1.0.

SIMNOMERGE algorithm

```
SCOREDOCUMENTSWITHSIMNOMERGE( $q, B, V, N, \text{normalizer}$ )
1  for  $n \leftarrow 1$  to  $N$ 
2  do  $\text{score}[n] \leftarrow 0$ 
3  for each  $\langle c_q, t \rangle \in q$ 
4  do  $w_q \leftarrow \text{WEIGHT}(q, t, c_q)$ 
5    for each  $c \in B$ 
6    do if  $\text{CR}(c_q, c) > 0$ 
7      then  $\text{postings} \leftarrow \text{GETPOSTINGS}(\langle c, t \rangle)$ 
8      for each  $\text{posting} \in \text{postings}$ 
9      do  $x \leftarrow \text{CR}(c_q, c) * w_q * \text{weight}(\text{posting})$ 
10      $\text{score}[\text{docID}(\text{posting})]_+ = x$ 
11 for  $n \leftarrow 1$  to  $N$ 
12 do  $\text{score}[n] \leftarrow \text{score}[n] / \text{normalizer}[n]$ 
13 return  $\text{score}$ 
```

Outline

- 1 Introduction
- 2 Basic XML concepts
- 3 Challenges in XML IR
- 4 Vector space model for XML IR
- 5 Evaluation of XML IR

Initiative for the Evaluation of XML Retrieval (INEX)

INEX: standard benchmark evaluation (yearly) that has produced test collections (documents, sets of queries, and relevance judgments).

Based on IEEE journal collection (since 2006 INEX uses the much larger English Wikipedia as a test collection).

The relevance of documents is judged by human assessors.

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INEX 2002 collection statistics

12,107	number of documents
494 MB	size
1995–2002	time of publication of articles
1,532	average number of XML nodes per document
6.9	average depth of a node
30	number of CAS topics
30	number of CO topics

INEX topics

Two types:

- ① content-only or **CO topics**: regular keyword queries as in unstructured information retrieval
- ② content-and-structure or **CAS topics**: have structural constraints in addition to keywords

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- 1 content-only or **CO topics**: regular keyword queries as in unstructured information retrieval
- 2 content-and-structure or **CAS topics**: have structural constraints in addition to keywords

Since CAS queries have both structural and content criteria, relevance assessments are more complicated than in unstructured retrieval.

INEX relevance assessments

INEX 2002 defined **component coverage** and **topical relevance** as orthogonal dimensions of relevance.

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Evaluates whether the element retrieved is “structurally” correct, i.e., neither too low nor too high in the tree.

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Component coverage

Evaluates whether the element retrieved is “structurally” correct, i.e., neither too low nor too high in the tree.

We distinguish four cases:

- 1 Exact coverage (E): The information sought is the main topic of the component and the component is a meaningful unit of information.
- 2 Too small (S): The information sought is the main topic of the component, but the component is not a meaningful (self-contained) unit of information.
- 3 Too large (L): The information sought is present in the component, but is not the main topic.
- 4 No coverage (N): The information sought is not a topic of the component.

INEX relevance assessments

The **topical relevance** dimension also has four levels: highly relevant (3), fairly relevant (2), marginally relevant (1) and nonrelevant (0).

INEX relevance assessments

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Combining the relevance dimensions

Components are judged on both dimensions and the judgments are then combined into a digit-letter code, e.g. 2S is a fairly relevant component that is too small. In theory, there are 16 combinations of coverage and relevance, but many cannot occur. For example, a nonrelevant component cannot have exact coverage, so the combination 3N is not possible.

INEX relevance assessments

The relevance-coverage combinations are quantized as follows:

$$\mathbf{Q}(rel, cov) = \begin{cases} 1.00 & \text{if } (rel, cov) = 3E \\ 0.75 & \text{if } (rel, cov) \in \{2E, 3L\} \\ 0.50 & \text{if } (rel, cov) \in \{1E, 2L, 2S\} \\ 0.25 & \text{if } (rel, cov) \in \{1S, 1L\} \\ 0.00 & \text{if } (rel, cov) = 0N \end{cases}$$

This evaluation scheme takes account of the fact that binary relevance judgments, which are standard in unstructured IR, are not appropriate for XML retrieval. The quantization function \mathbf{Q} does not impose a binary choice relevant/nonrelevant and instead allows us to grade the component as partially relevant.

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This evaluation scheme takes account of the fact that binary relevance judgments, which are standard in unstructured IR, are not appropriate for XML retrieval. The quantization function \mathbf{Q} does not impose a binary choice relevant/nonrelevant and instead allows us to grade the component as partially relevant. The number of relevant components in a retrieved set A of components can then be computed as:

$$\#(\text{relevant items retrieved}) = \sum_{c \in A} \mathbf{Q}(rel(c), cov(c))$$

INEX evaluation measures

As an approximation, the standard definitions of precision and recall can be applied to this modified definition of relevant items retrieved, with some subtleties because we sum graded as opposed to binary relevance assessments.

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Overlap is not accounted for. Accentuated by the problem of multiple nested elements occurring in a search result.

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Recent INEX focus: develop algorithms and evaluation measures that return non-redundant results lists and evaluate them properly.

Recap

- Structured or XML IR: effort to port unstructured (standard) IR know-how onto a scenario that uses structured (DB-like) data
- Specialised applications (e.g. patents, digital libraries)
- A decade old, unsolved problem
- <http://inex.is.informatik.uni-duisburg.de/>