Query Operations

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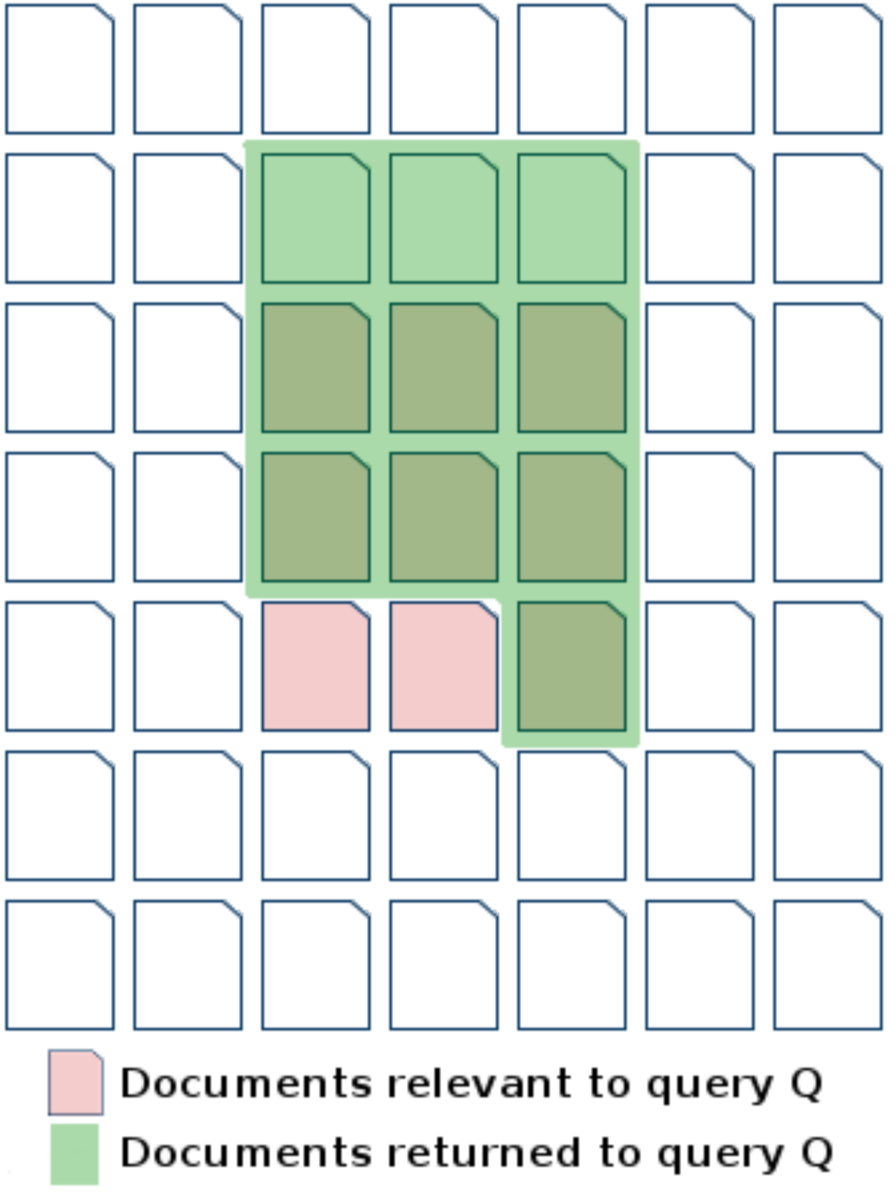
Outline

- Introduction
- Feedback information from the user
- Expansion based on local set of documents
- Expansion based on global set of documents
- Conclusions

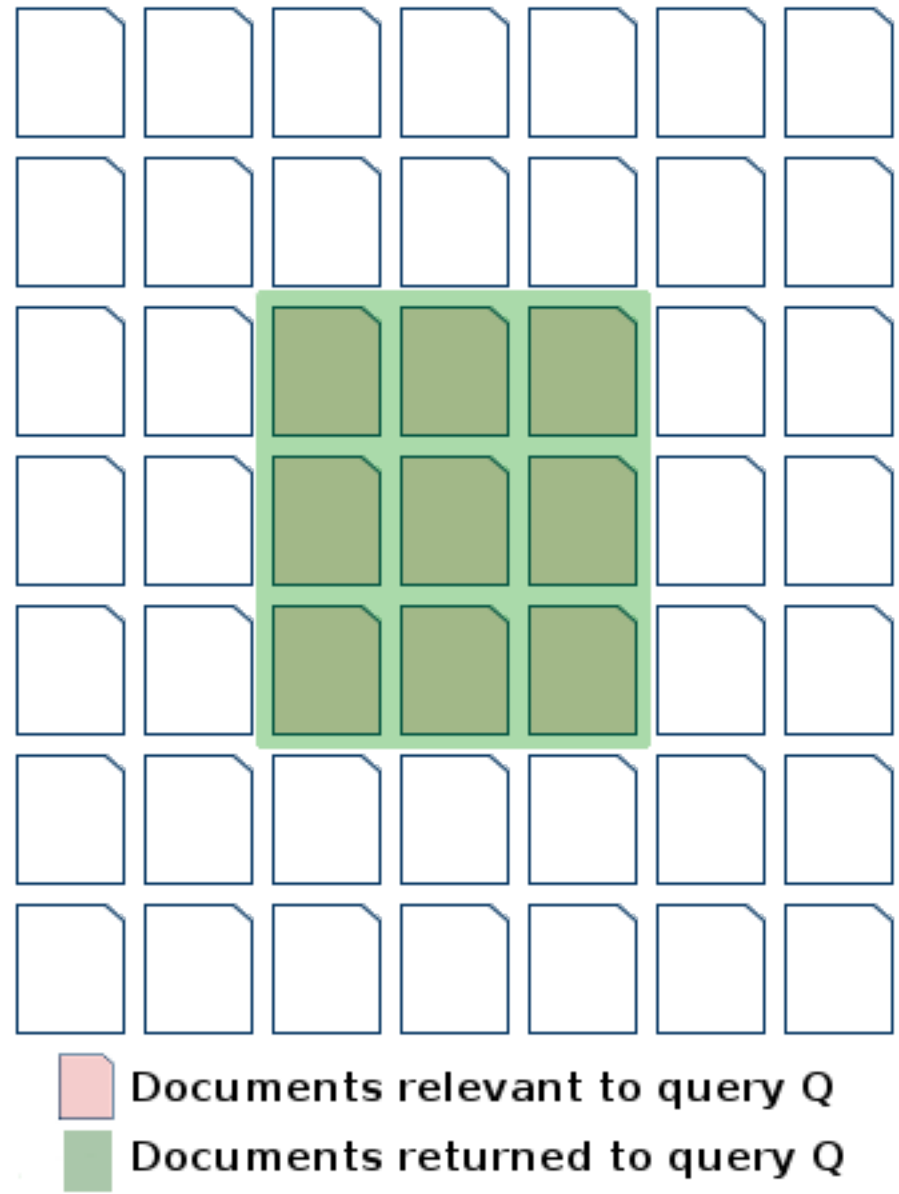
Introduction

- Increase number of relevant documents
- Decrease number of irrelevant documents



Introduction (cont.)

- Increase number of relevant documents
- Decrease number of irrelevant documents
- Ideal case

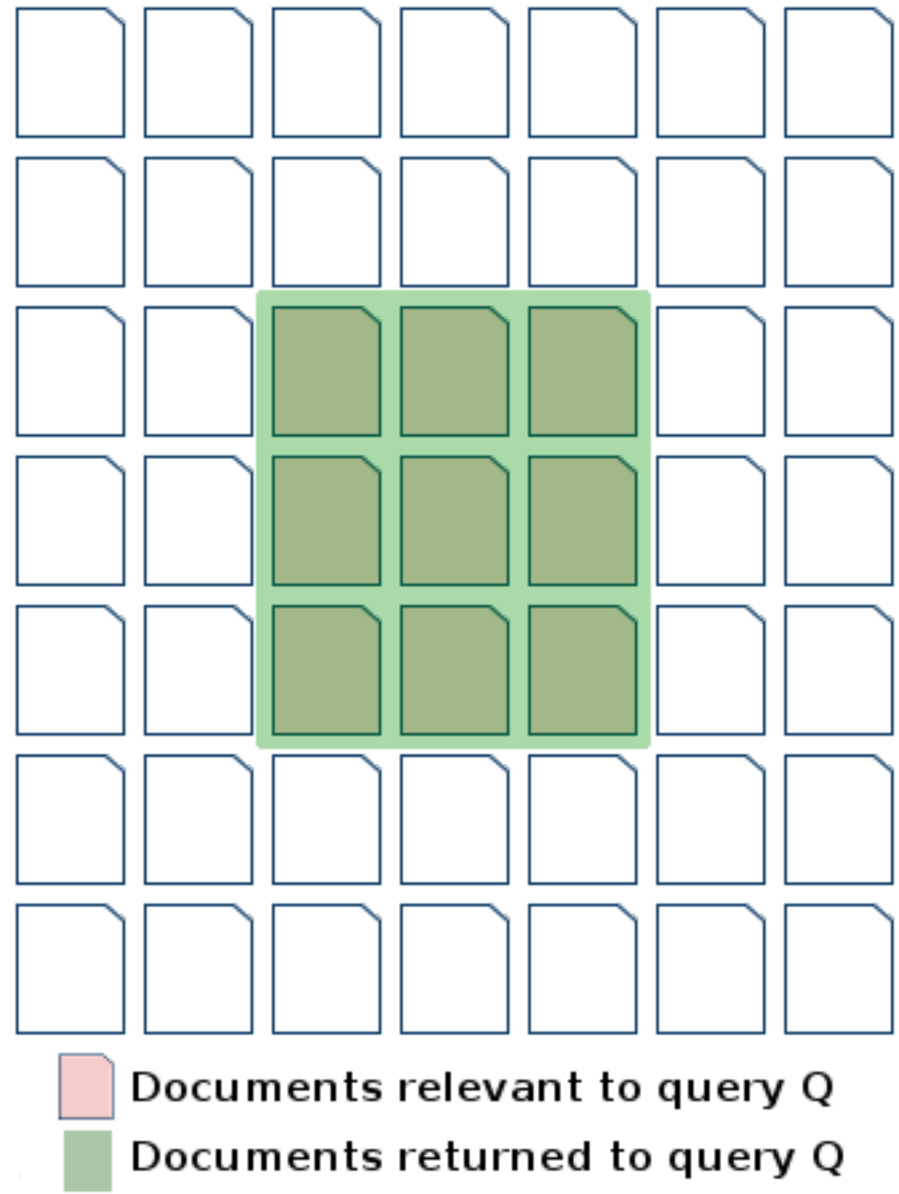


Introduction (cont.)

- Increase number of relevant documents
- Decrease number of irrelevant documents
- Ideal case

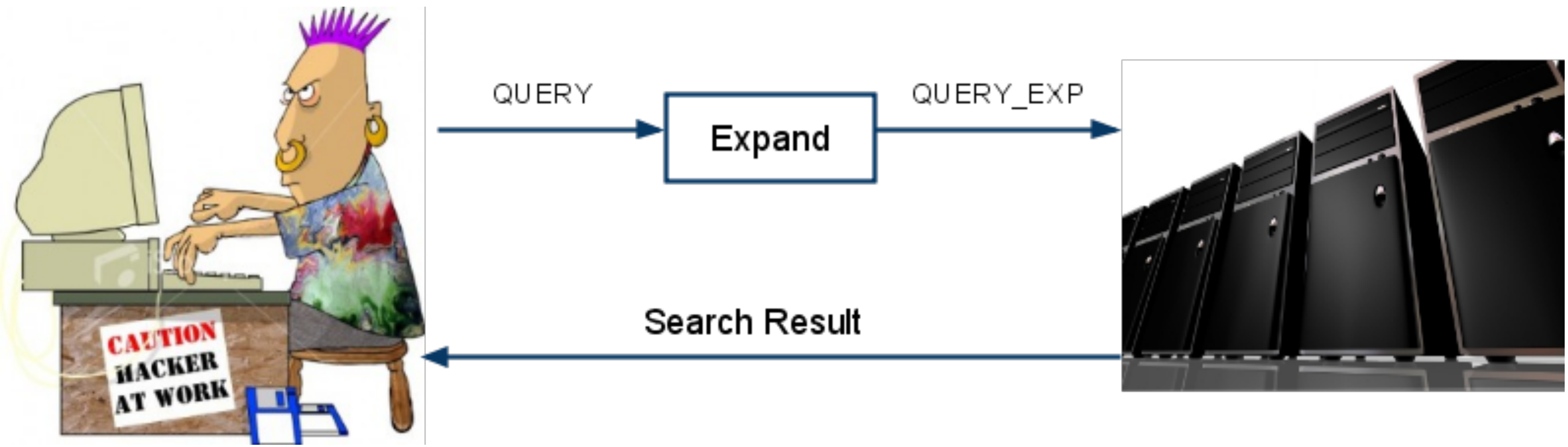
- Expansion of initial query
  - add synonyms
  - remove garbage terms

Example
initial = "a car"
expanded = "car vehicle automobile"



Introduction (cont.)

- Initial query which we receive from user is never good enough to directly fetch the documents. It needs to be expanded



In this presentation I will explain different methods, how expansion can be performed

Vector Space Model

- Algebraic model to represent documents
- Vector representation of a document

$$v_d = [w_1, w_2, w_3, w_4, \ldots]$$

***w_i* - weight of a term i in a document**

$$w_{t,d} = \frac{n_{t,d}}{\sum_k n_{k,d}} \cdot \log \frac{|N|}{|t \in d|}$$

term* = *word

$n_{t,d}$ - number of terms ***t*** in document ***d***

$\sum_k n_{k,d}$ - number of all terms in document ***d***

$|N|$ - number of documents in document set

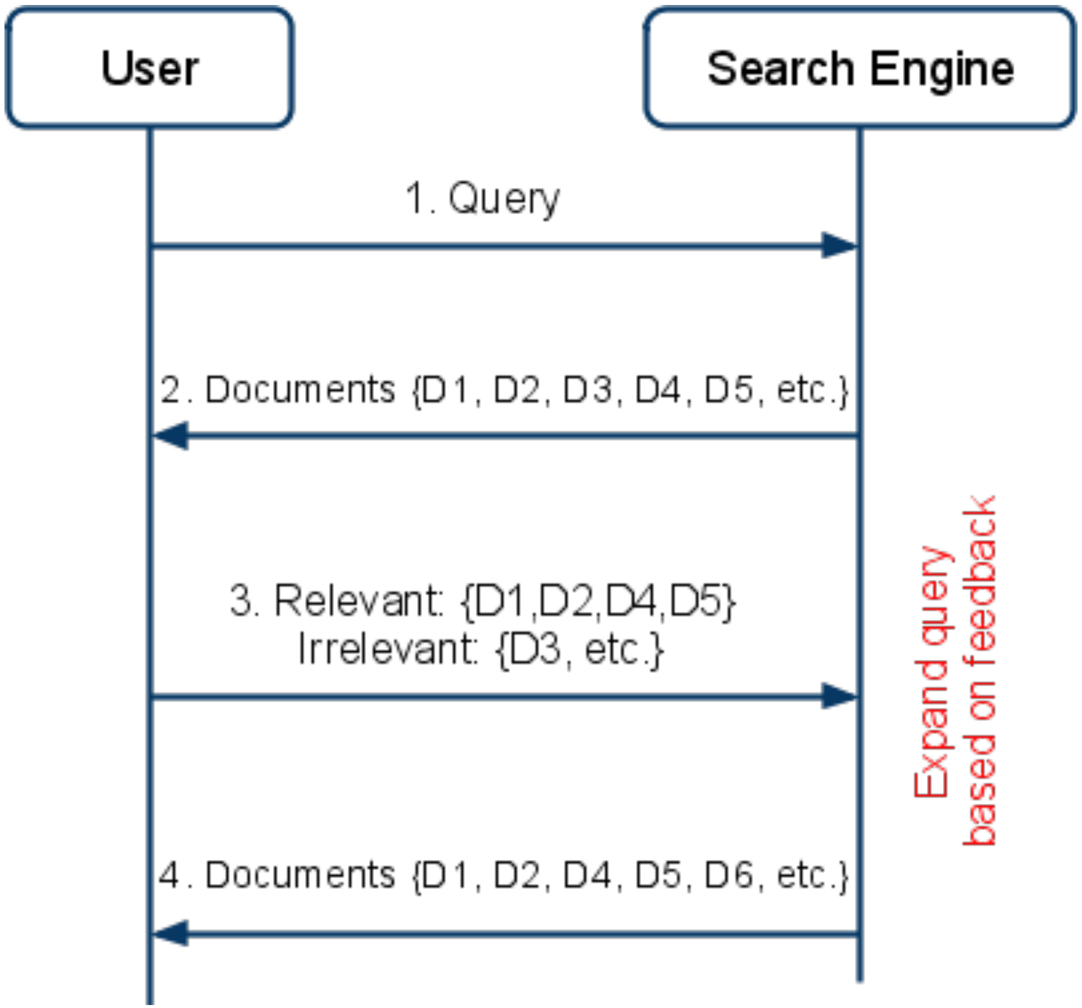
$|t \in d|$ - number of documents containing term ***t***

Further...

- Introduction
- **Feedback information from the user**
- **Expansion based on local set of documents**
- **Expansion based on global set of documents**
- Conclusions

Feedback information from the user

1. User sends query **Q** to the search engine
2. Search engine retrieves all documents corresponding to query **Q**
3. Out of documents retrieved, user selects relevant ones and irrelevant ones and provides that information as a feedback to search engine
4. Based on this feedback search engine expands the query and returns improved search results



Feedback information from the user (cont.)

- <u>Query expansion - Vector Model</u>

$$\vec{q}_{expanded} = a \cdot q_{original} + \frac{b}{|D_r|} \cdot \sum_{\forall \vec{d}_j \in D_r} \vec{d}_j - \frac{c}{|D_n|} \cdot \sum_{\forall \vec{d}_j \in D_n} \vec{d}_j$$

a,b,c - tuning constants
D_r - relevant documents returned by original query
D_n - irrelevant documents returned by original query

- <u>Query expansion - Probabilistic Model</u>

$$\vec{q}_{expanded} = \sum_{i=1}^{t} w_{i,q} \cdot w_{i,D} \cdot \left(\log \frac{P(k_i \mid D_r)}{1 - P(k_i \mid D_r)} + \log \frac{1 - P(k_i \mid D_n)}{P(k_i \mid D_n)}\right)$$

$w_{i,q}$ - weight of i-th term in original query q | t - number of terms in original query
$w_{i,D}$ - weight of i-th term in set of all returned documents
$P(k_i \mid D_r)$ - probability of finding term k_i in relevant documents
$P(k_i \mid D_n)$ -probability of finding term k_i in irrelevant documents

Feedback information from the user (cont.)

- *Vector Model*
  - adds important terms to original query, based on relevant documents
  - removes unimportant terms from original query, based on irrelevant documents
- *Probabilistic model*
  - recalculates weights (importance) of query terms - some query terms are more important others less
  - doesn't add or remove terms

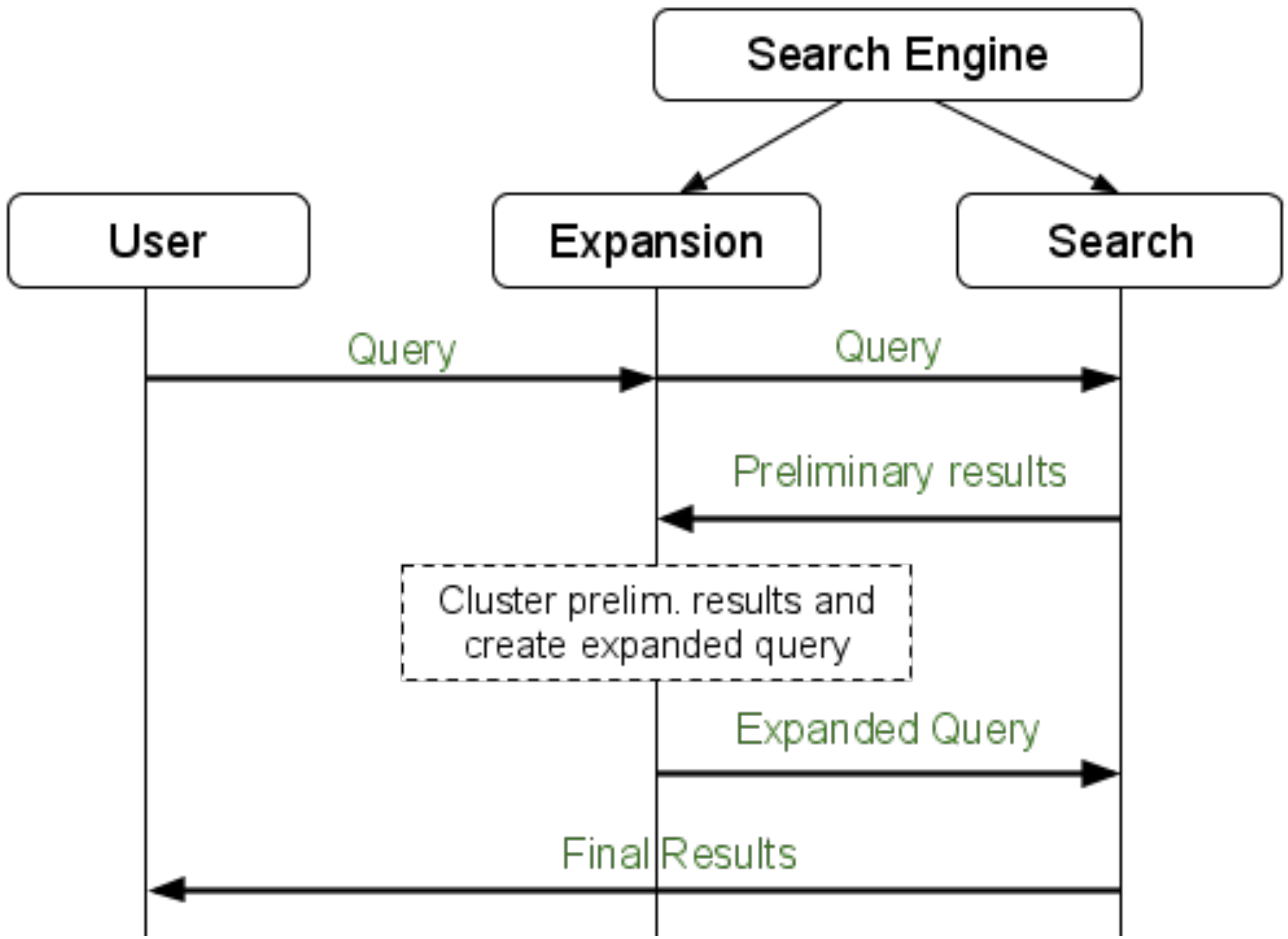
\+ relevant/irrelevant documents are determined with high precision

\- need user interaction to identify relevant/irrelevant documents

Expansion based on local set of documents

- Let's try to cluster relevant/irrelevant documents returned by original query automatically, without user intervention

Local set of documents = *documents retrieved by initial query*



Association Clustering

- Tries to find synonyms for query terms
  - terms that occur frequently in the same document are likely to be synonyms (or at least are related)

m

	D1	D2	D3
t1	$f_{1,1}$	$f_{1,2}$	$f_{1,3}$
t2	$f_{2,1}$	$f_{2,2}$	$f_{2,3}$
t3	$f_{3,1}$	$f_{3,2}$	$f_{3,3}$

*

m^T

	t1	t2	t3
D1	$f_{1,1}$	$f_{2,1}$	$f_{3,1}$
D2	$f_{1,2}$	$f_{2,2}$	$f_{2,2}$
D3	$f_{1,3}$	$f_{2,3}$	$f_{3,3}$

=

$m*m^T$

	t1	t2	t3
t1	t1*t1	t1*t2	t1*t3
t2	t2*t1	t2*t2	t3*t2
t3	t3*t1	t3*t2	t3*t3

- Resulting matrix is called correlation matrix and it represent co-occurrence of terms in the same document.
- The higher is the correlation, more often terms occur in the same document

Association Clustering: Example

$m*m^T$

	t1	t2	t3
t1	t1*t1	t1*t2	t1*t3
t2	t2*t1	t2*t2	t3*t2
t3	t3*t1	t3*t2	t3*t3

If *t3*t1* and *t3*t2* are sufficiently large, it means that terms *t3, t2, t1* occur frequently together in the documents and thus form association cluster around *t3* .

Hence query which contains term *t3* can be expanded with terms *t2* and *t1*

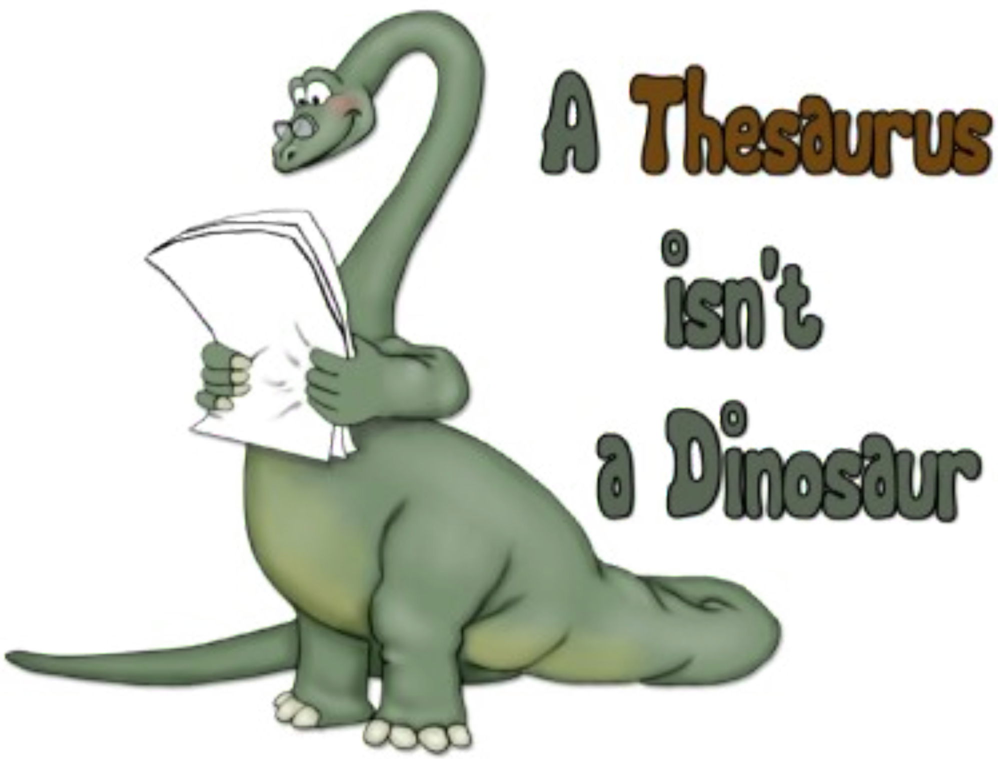
Metric Clustering

- Metric clustering considers distance between terms
- Terms close to each other, in the text, are more likely to be related, than terms farther from each other.
- Correlation matrix contains average distances of terms from each other based on local document set.

Expansion based on local set of documents (cont.)

- Allows to automatically expand query based on documents retrieved from the initial query
- Can create a lot of overhead, because for each query correlation matrices should be recalculated
- Hence method is unsuitable for systems where query response times should be small.

Expansion based on global set of documents



- Similar to expansion using local set of documents with association clustering.
- Correlation matrix is computed for all the documents in system.
- Resulting structure is called Thesaurus.
- Creating such huge structure is computationally expensive, but it should be done only once and later it can be incrementally updated.

Global set of documents = *all the documents in the system*

Approach based on global set of documents (cont.)

<u>Query processing is performed as follows:</u>

- **Query is represented as terms:**

  $q = (t_1, t_2, t_{3, \ldots})$

- **Based on thesaurus, find all the document terms similar to query terms:**

  $(k_1, k_2, k_3, \ldots)$ *are similar to terms* $(t_1, t_2, t_{3, \ldots})$

- **For each similar term we compute how similar it is to the whole query:**

  Similarity of $(k_1, k_2, k_3, \ldots)$ *to whole* q

- **Expand the original query with terms which are the most similar to the original query.**

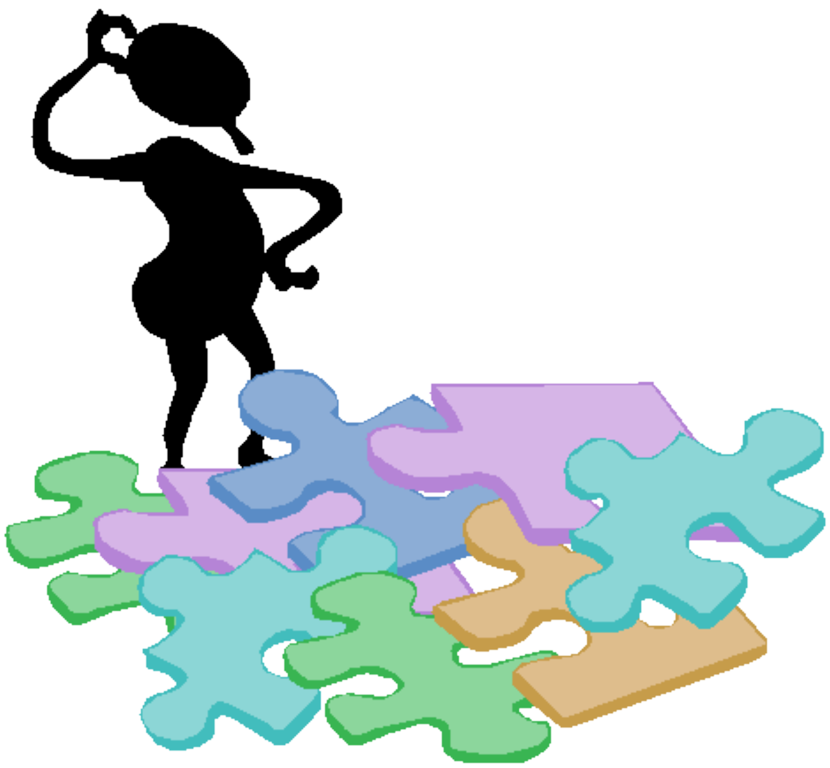
Approach based on global set of documents (cont.)

- No need to query for documents twice
- Suitable for systems where small response times are required
- Improves retrieval performance in range of 20%

Conclusions

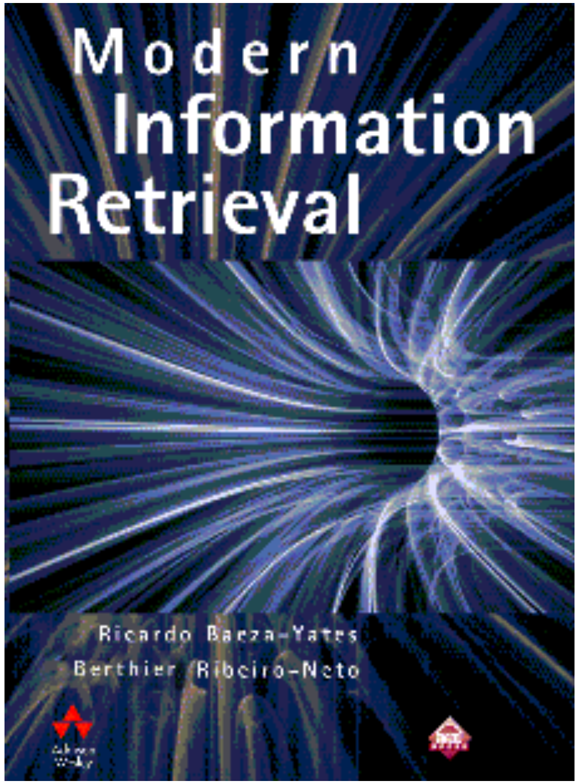
- Techniques of expanding the query for improving relevancy of search engine responses.

- No silver bullet, each approach is good for it's own purpose
  - User feedback based
  - Local document set based
  - Global document set based



References

- Modern Information Retrieval, Chapter 5, Query Operations, book by Ricardo Baeza-Yates and Berthier Ribeiro-Neto



Thank You!