On Content-Driven Search-Keyword Suggesters for Literature Digital Libraries

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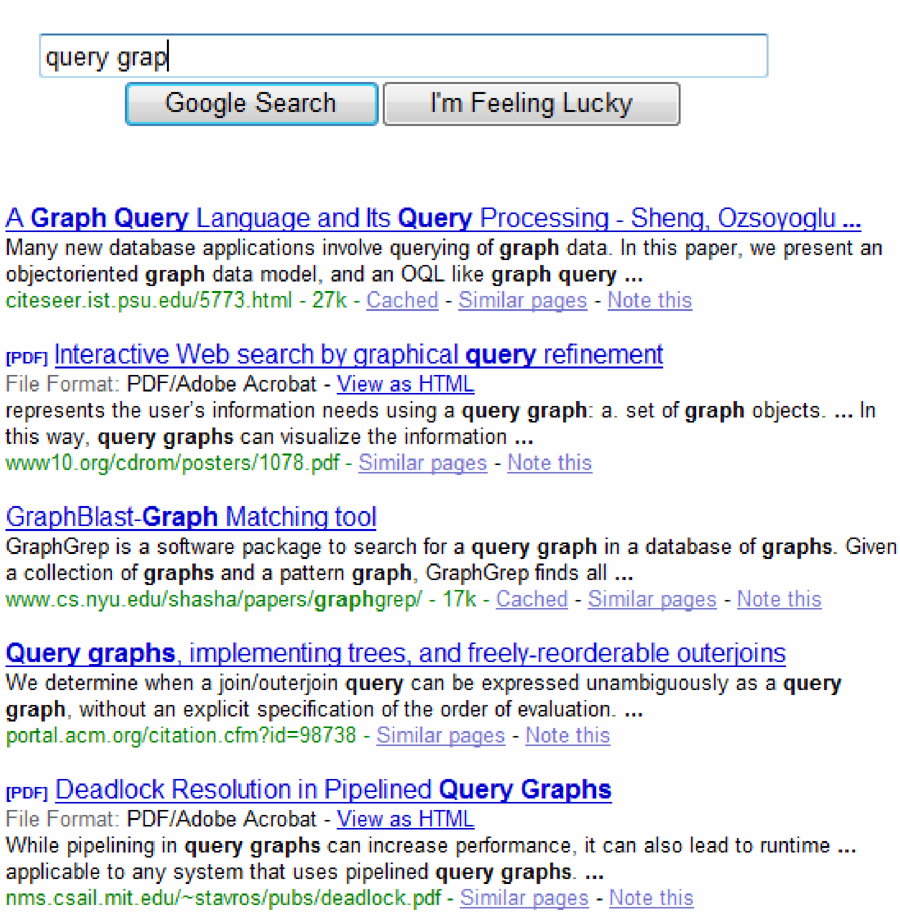
Online Literature Digital Libraries Current Status

- No Search keyword-suggesters
  - IEEE Explore
  - ACM Digital Library
  - PubMed
  - ScienceDirect
- Search History-Based Keyword-Suggester
  - Google Scholar – through Google Suggest
- Content-Driven Keyword-Suggester
  - The CompleteSearch engine, experimental

Why Search-Keyword Suggestion?

- helpful for constructing search keywords for queries that are
  - more accurate,
  - less ambiguous, and
  - more focused
- users spend considerable amounts of time in search sessions
  - to properly select keywords, and
  - to modify their search keywords in order to successfully locate relevant documents.

Google Suggest Approach

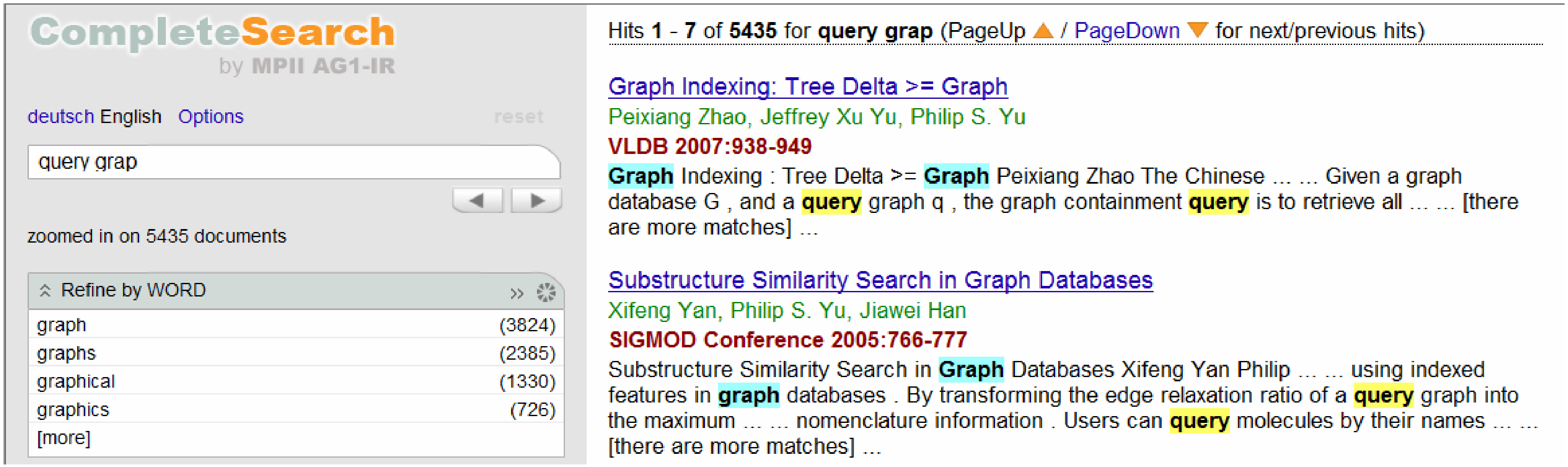


Left: No suggestions, however, relevant documents exist.
Up: Suggesting from Search history and the expected output sizes.

Search-History Based SKS

- Google's SK-Suggester
  - utilizes the search history of all users as keyword suggestions
  - recommends keywords from
    - (i) popular searches,
    - (ii) searches from the current user's search history,
    - (iii) current user's bookmarks.
- Drawbacks
  - Noisy keywords; typos from users included as suggestions
  - Incorrect search-characterization, not well-characterized search terms.
  - Bias to users' interests
  - Needs comprehensive search history maintenance
  - High processing and maintenance costs

The CompleteSearch Engine



Searching the CompleteSearch Engine for “query grap”

- Actual execution of query.
- Text-snippets from the document collection are returned;
  needs preprocessing by the user.

The CompleteSearch engine Approach

- Prepare the HYB index, pre-compute inverted lists of unions of words.
- Unions of words are identified using proximity measures between words separated by ***w*** (a pre-determined window size).
- Similar words are placed in the same block within the index
  - Maintains a good level of *locality of search*,
  - As the user enters his search words, relevant blocks determine the *(searching) scope*,

Content-Based SK-Suggester

- Content-Based SK-Suggester anticipates users' search keywords.
  General Approach:
  - (i) parse the document collection to be searched,
  - (ii) prepare offline refinements to search keywords, and
  - (iii) dynamically suggest keywords as the user types his/her keywords

Our Approach

(i) Parse the document collection: *Link Grammar parser.*

- a syntactic parser of English,

(ii) Group publications.

- "most-specific" research topics (research pyramids),

(iii) Within each research pyramid (RP), build a hierarchical structure of simple and compound tokens (phrases), islands

(iv) Attach topic-(RP-)sensitive scores to keywords

- use TextRank, a text summarization tool,

(v) Use the identified *research-topics* to help user choose more focused search keywords *prior to actual search query execution*.

Utilized Tools

The Link-Grammar English Parser
The Research-Pyramid Based Grouping Utility
TextRank Algorithm

Linguistic Pre-Processing Step

Tokenize documents

- transforms documents into a categorized block of text, called *tokens*

Form *compound tokens:* combine two or more simple tokens at a time

- Builds syntactically and semantically correct suggestions (using the link-grammar output)

Example: Tokenize the paper title:

"*The Linear Complexity of a Graph*":

Generate *simple* tokens

(i) “the”, "of" and “a” which are *stopwords*, and

(ii) "linear", “complexity”, and "graph" which are *non-stopwords*.

(iii) form *compound tokens:* “linear complexity”.

Link-Grammar Parser

```
                               +-------------Jp-------------+
                               |      +----------A----------+
    +-----AN-----+             |      |         +-----A-----+
    |            |             |      |         |           |
outlier.n detection.n for.p high.a dimensional.a data.n
```

```
                     +-----------Op-----------+ L2
+-Ds-+     +---Mgp--+          +-----A-----+ L1
|    |     |        |          |           |
a model.n for.p querying.v annotated.v documents.n
```

Link-Grammar Parser

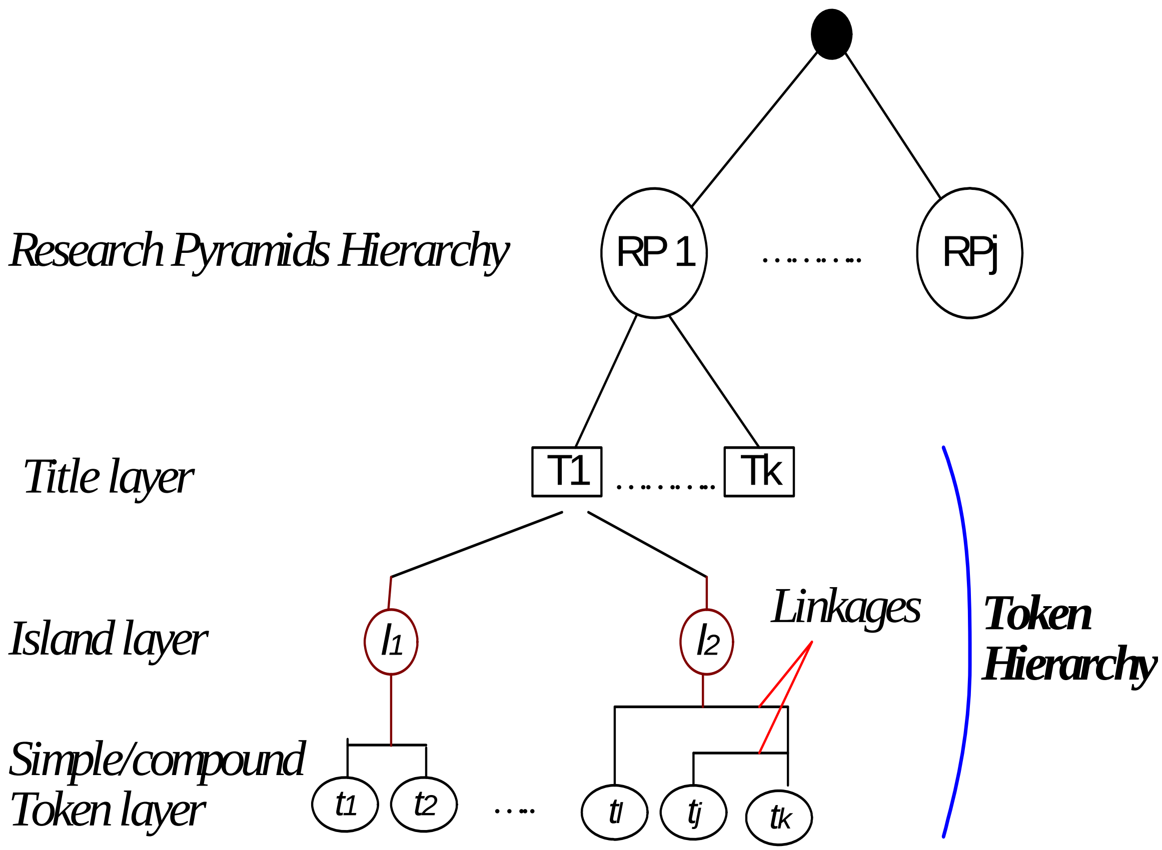
Observed linkage types and their percentages

Linkage type	% across ACM SIGMOD Anthology	Information
(A)	24.35	Connects adjective to noun
(AN)	23.43	Connects noun-modifier to noun
(J)	18.28	Connects preposition to its objects
(D)	8.42	Connects determinator to noun
(M)	8.69	Connects noun to post-noun modifiers
(MV)	4.46	Connects verbs to adjectives
(O)	6.15	Connects transitive verbs to objects

Frequency of each observed parts-of-speech token

Part of Speech	Frequency	Part of Speech	Frequency
Nouns	47.32	Adverbs	0.076
Adjectives	15.23	Clauses	0.069
Verbal nouns	10.65	Relative clauses	0.025
Prepositions	4.48	Un-tagged	21.14

Token Hierarchy

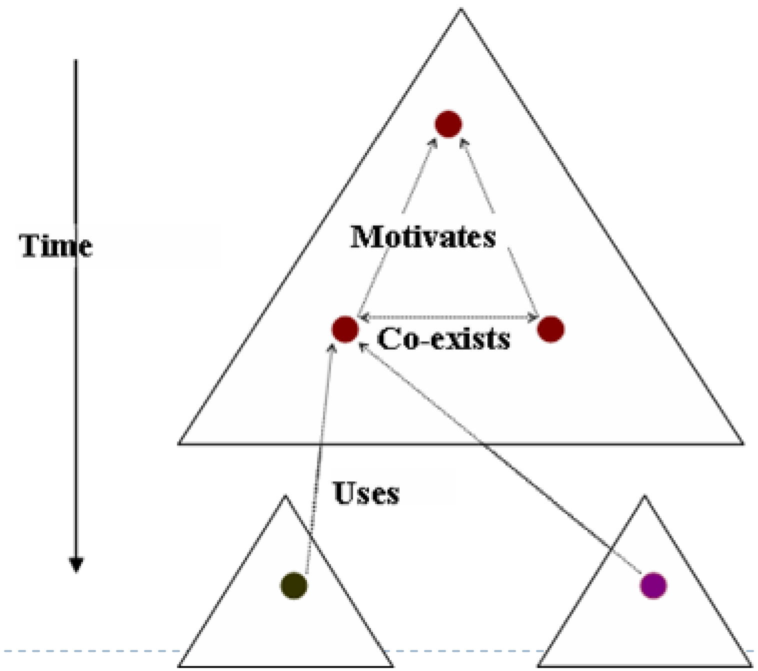


The Research-Pyramid Model

- The Research Pyramid Model of Research Evolution

  Publications in any scientific discipline are 'naturally' categorized into groups called 'research pyramids'.

- A **research pyramid (RP) :** publications that belong to a most-specific research topic.
- Each RP has a pyramid-like structure in terms of the citation graph



The Research-Pyramid Model

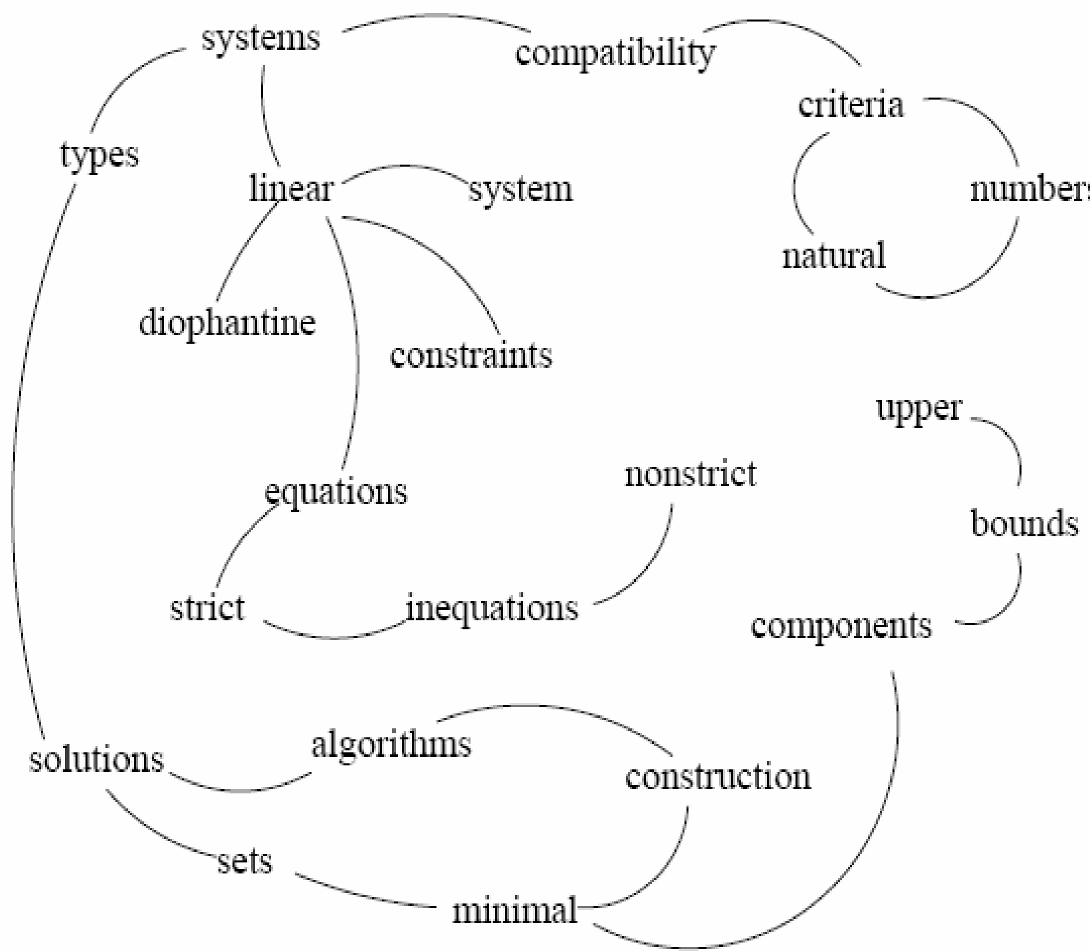
- The goal of each *user search session:*
  - find information about a specific topic.
- (The *locality of search* principle):

Within a single search session,
the user targets documents
within a specific topic (i.e., an RP).

- SK suggestion scope
  - chosen as close to the topic being targeted as possible.
- As user enters more search keywords:
  - prune out topics (keywords) that are of low significance.
- Single token (word) significance => TextRank

TextRank Algorithm

- Used to compute Topic-Sensitive Token and Phrase Weights.
- Vertices are **filtered** tokens (nouns and adjectives),
  - Syntactic filter
- Links represent linguistic/textual adjacency (in our case, they appear in the same title)
- Each graph for a research-pyramid is **topic-sensitive.**



Advantages of Our Approach

- Eliminates the drawbacks of Google’s search history-based SK-Suggester.
- Boosts the performance of the techniques used in the CompleteSearch.
- Has an excellent locality of access.

Main Modules of the Content-Driven SK-Suggester

Procedure *SK-SuggesterInterface* ()

Input

User Input ***w*** : current search-terms

Server Input : R, and I (stored in session status)

{

(1) For ***w***

(1.1) LISK <- the uncompleted search keyword in ***w***

(1.2) CSK <- the completed search keywords in ***w***

(1.3) If (CSK="" && LISK!="")

STA_Module(*LISK****);***

(1.4) Elseif (CSK!="" && LISK="")

QR_Module(*CSK, LISK****);***

(1.5) Elseif (CSK!="" && LISK!="")

SK-List1 <- ***STA_Module(*** *LISK****);***

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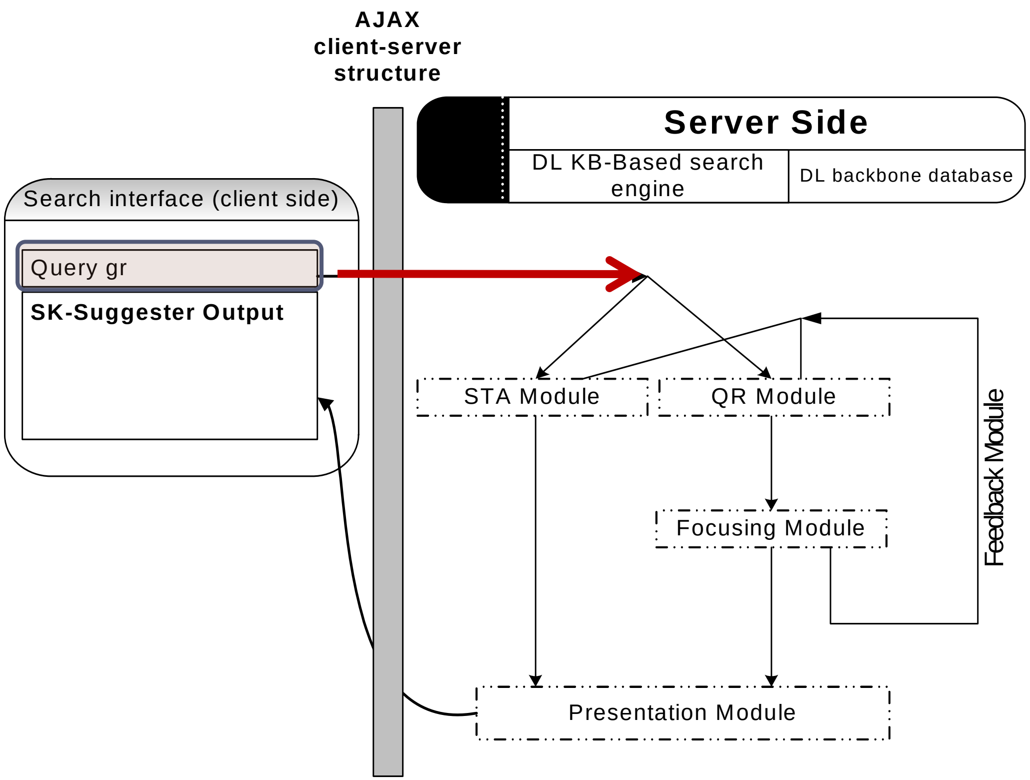
Join(SK-List1, SK-List2)

(2) **Presentation_Module**(W')



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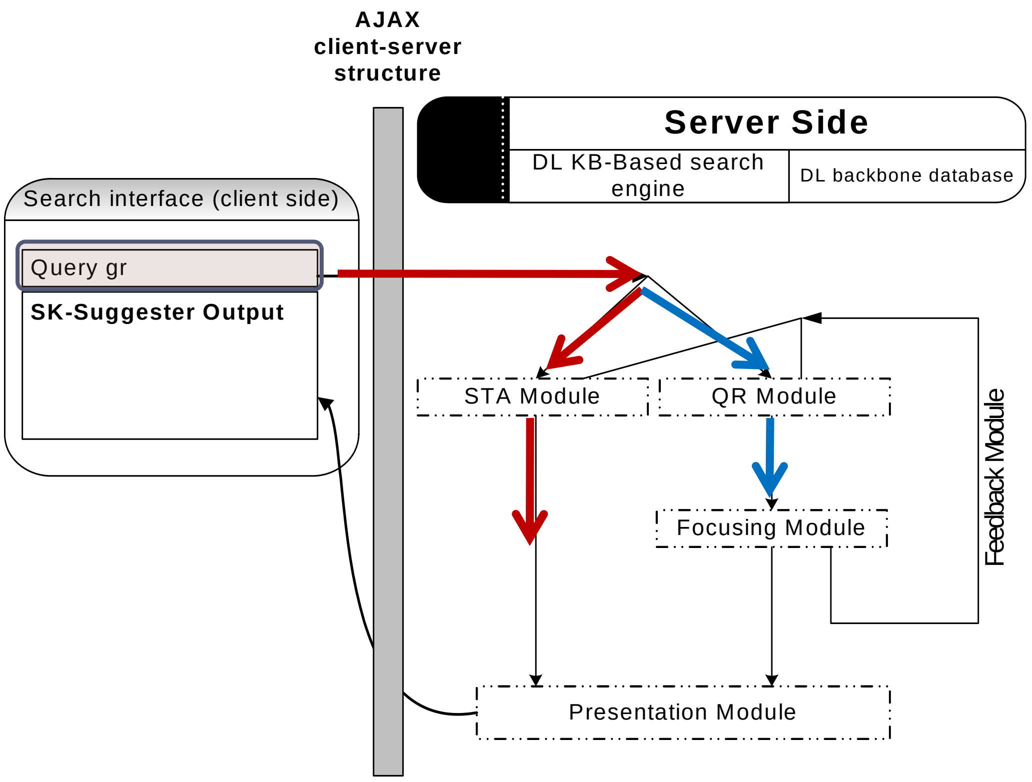

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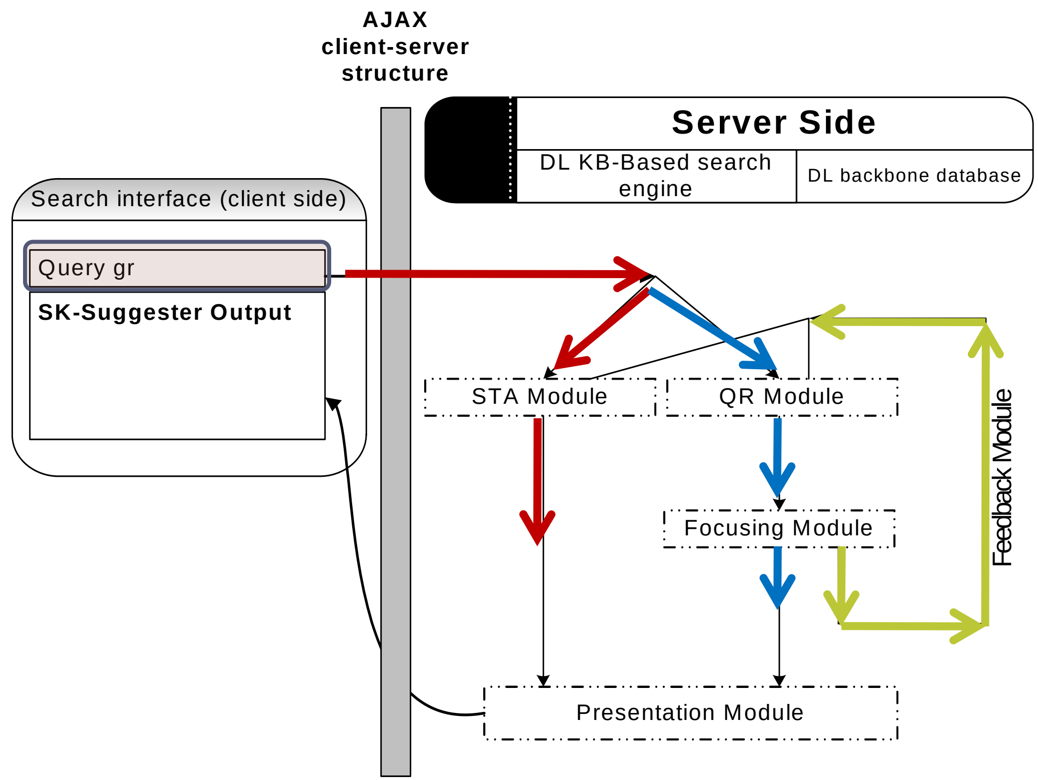

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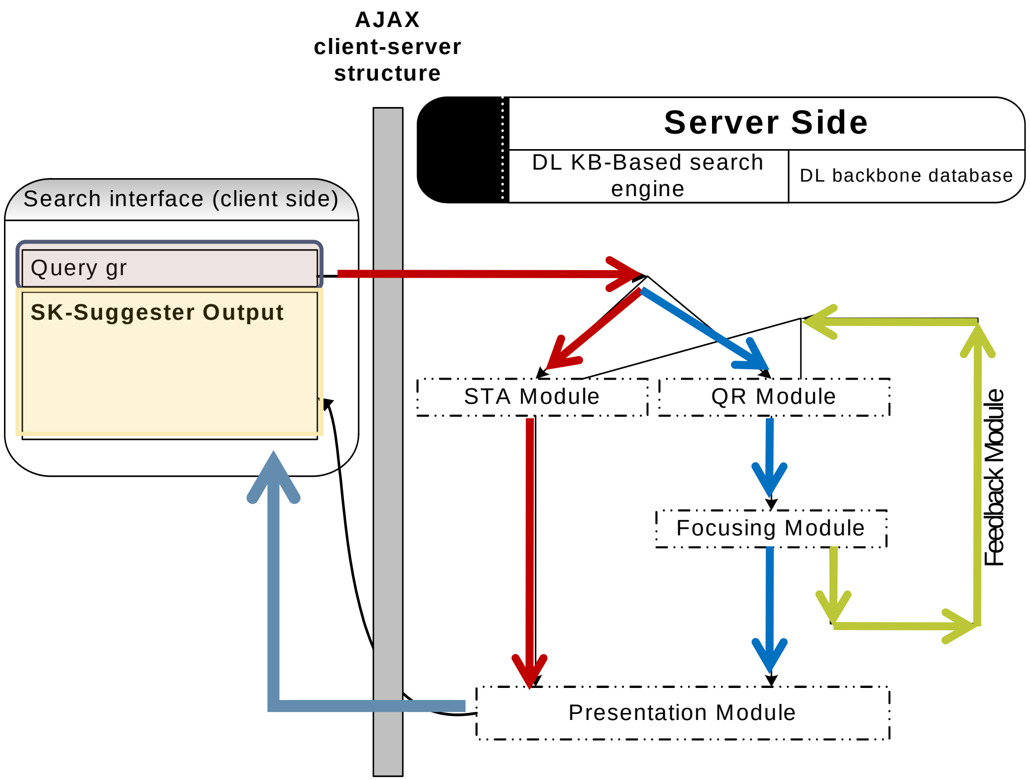


Guiding statistics provided to the user online

- Suggestion Scope
  - the number of research topics (or research pyramids) where the search keywords ***w*** are observed
- Topic-Sensitive Popularity of Search Keywords TSP(W', **r**)
  - W': search terms
  - the sum of TextRank scores of all words in W'
  - Query refinements (W'): presented in the order of their ***matching scores***:
  - Similarity(W', W): text-based similarity between W' and the search terms W

$$M_{Score(W',W)} = Similarity(W',W) * Max_{r \in RP(W')}[TSP(W',r)]$$

Experimental Results and Observations

Accuracy of Linguistic Pre-processing and Quality of Suggestions

Scalability and Index Sizes

Convergence of Suggestion Scope

Untagged Tokens

Token	% of untagged tokens	Token	% of untagged tokens
of	17.39	to	4.72
a	14.76	an	4.51
in	14.30	on	3.43
and	14.12	with	3.34
the	11.92	from	1.62

The distribution of un-tagged tokens

- Untagged tokens are all stopwords.
- We use them
  - (i) to construct islands and
  - (ii) to connect linguistically adjacent islands.

K-word Proximity Search

- The search keywords “query graph” are already identified as one island.
- Suggesting query refinements based on islands may help towards a successful proximity search.
- Notice that item (3) is probably irrelevant to the query at search time since this publication most probably belongs to different research pyramid from the first and second hits; this false positive is pruned or pushed down in ranking query results.
- Informing users of the linguistic proximity of search terms prior to query execution can thus be useful.
- Furthermore, informing the user of the order in which terms appear may help eliminate false hits like hit (4), which is called k-word ordered proximity search.

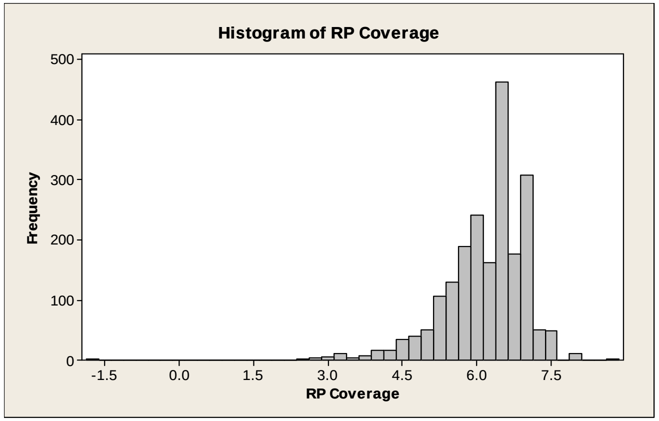
(1) Multiple Query Processing In Deductive Databases **Using** Query Graphs
(2) Query Graphs Implementing Trees And Freely Reorderable Outerjoins
(3) Effective Graph Clustering For Path Queries In Digital Map Databases
(4) Query By Diagram, A Graphic Query System

Possible hits of the query “query graph”

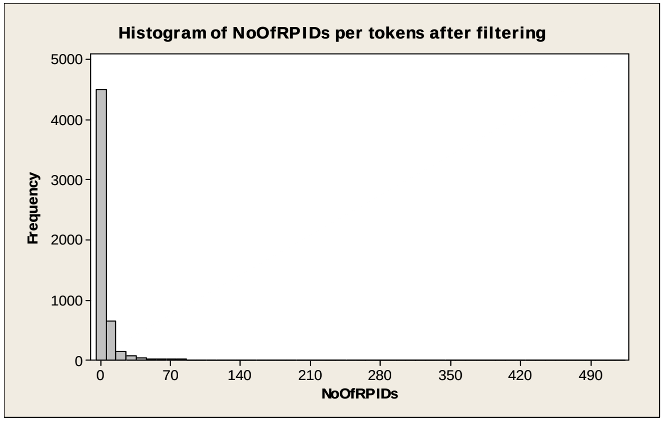
Convergence of Suggestion Score

Coverage(**r**)= -log[(# of tokens used in **r**)/(total # of tokens)]

- Coverage values range between 3 and 8, which means that
  - (i) the tokens within each research pyramid are of low diversity, and
  - (ii) this signifies the importance of ranking tokens within research topics.
  - This serves to push refinements extracted from dominant research topic(s) up in the suggestion list.
- **Observation:** Filtered tokens have limited scope.



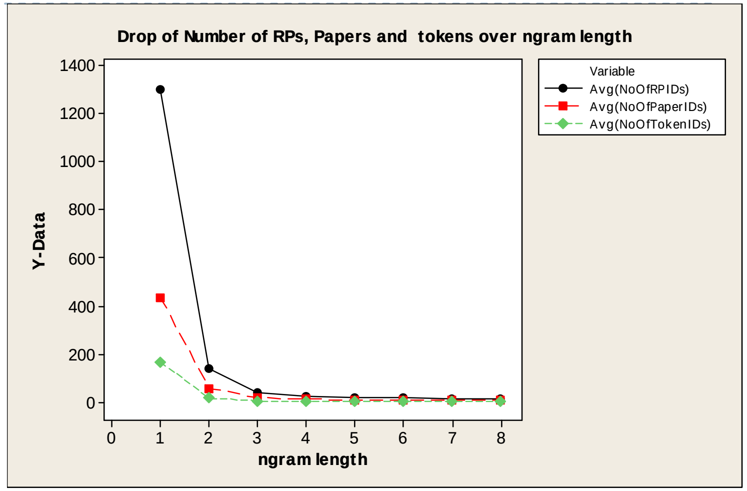
Distribution of RP coverage



Distribution of token scope (after filtering)

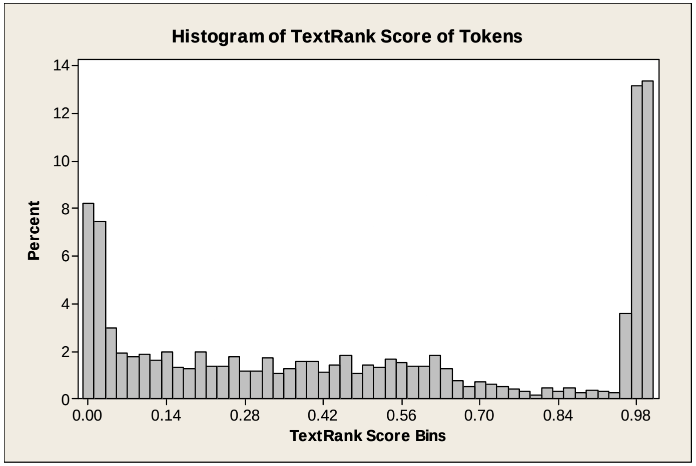
Convergence of Suggestion Score

- Search-keyword suggestion can be optimized reducing suggestion scope
  - Suggestion scope converges fast.



Suggestion scope vs ngram length

- High TextRank => more significant tokens.
- Tokens that score high (>0.8): content-bearing of the corresponding research pyramid.
- Low-scored tokens: widely used tokens.
- Order SK-suggester output
  - Significant refinements from dominant research pyramids.



Distribution of TextRank scores for simple tokens

Future Work

- Our proposed approach can be used on any document collection given that
  - documents are clustered
  - highly topically related clusters.
- *Hybrid search-keyword suggester* (i.e. content-driven and search-history based).
  - Initially, no search-history => suggest document contents.
  - track users' search terms
  - Build search-history.
- Why Hybrid SK-suggesters? combine the advantages of both approaches
  - (i) accurate search-history keywords, less **incomplete** or **misspelled** words,
  - (ii) well-characterized queries. Keywords from successful searches
  - (iii) personalized search-keyword suggestions. *Which is an advantage of Google's search-history based suggester.*

Questions?

Project website:

http://dblab.case.edu:8080/giza/doku.php