Chapter 7

Queries: Languages & Properties

Query Languages
Query Properties

Queries: Languages & Properties

- This chapter covers the main aspects of queries, including
  - the different languages used to express them
  - their distribution and approaches for analyzing them with focus on the Web

Query Languages

Query Languages

- We cover now the **different kind of queries** normally posed to text retrieval systems
- This is in part dependent on the retrieval model the system adopts
  - That is, a full-text system will not answer the same kind of queries as those answered by a system based on keyword ranking

Query Languages

- There is a difference between **information retrieval** and **data retrieval**
- Languages for information retrieval allow the answer to be ranked
- For query languages not aimed at information retrieval, the concept of ranking cannot be easily defined
  - We consider these languages as languages for data retrieval
  - Some query languages are not intended for final users

Query Languages

- There are a number of techniques to enhance the usefulness of the queries
- Some examples are the expansion of a word to the set of its synonyms or the use of a thesaurus
- Some words which are very frequent and do not carry meaning (called ***stopwords***) may be removed
- We refer to words that can be used to match query terms as **keywords**

Query Languages

- Another issue is the subject of the **retrieval unit** the information retrieval system adopts
- The retrieval unit is the basic element which can be retrieved as an answer to a query
- We call the retrieval units simply **documents**, even if this reference can be used with different meanings

Query Languages

Keyword Based Querying

Keyword Based Querying

- A **query** is the formulation of a user information need
- Keyword based queries are popular, since they are intuitive, easy to express, and allow for fast ranking
- However, a query can also be a more complex combination of operations involving several words

Word Queries

- The most elementary query that can be formulated in a text retrieval system is the **word**
- Some models are also able to see the internal division of words into letters
  - In this case, the alphabet is split into **letters** and **separators**
  - A word is a sequence of letters surrounded by separators
- The division of the text into words is not arbitrary, since words carry a lot of meaning in natural language

Word Queries

- The result of word queries is the set of documents containing at least one of the words of the query
- Further, the resulting documents are ranked according to the degree of similarity with respect to the query
- To support ranking, two common statistics on word occurrences inside texts are commonly used
  - The first is called **term frequency** and counts the number of times a word appears inside a document
  - The second is called **inverse document frequency** and counts the number of documents in which a word appears

Word Queries

- The other possibility of interpreting queries, popularized by Web search engines, is the **conjunctive form**
  - In this case, a document matches a query only if it contains all the words in the query
- This is useful when the number of results for one single word is too large
- Additionally, it may be required that the exact positions in which a word occurs in the text should be provided
- This might be useful for highlighting word occurrences in **snippets**, for instance, during the display of results

Context Queries

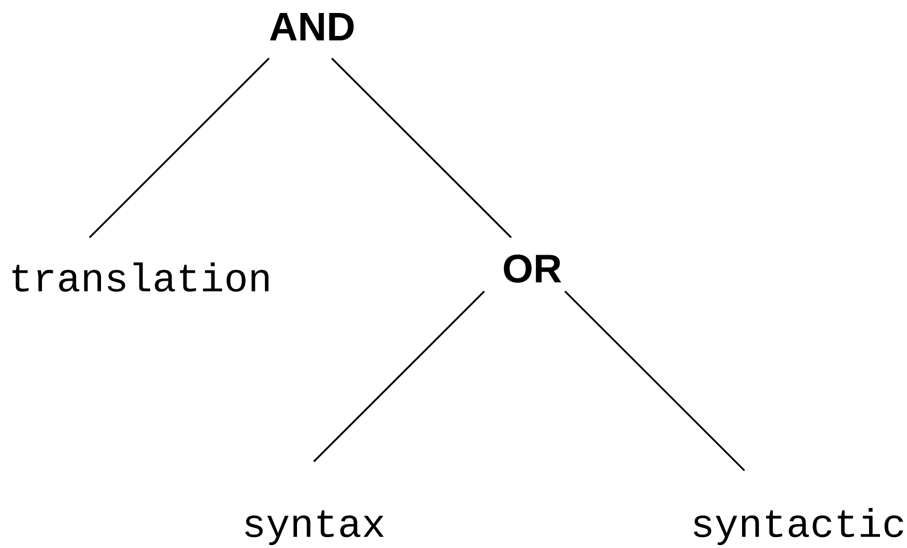
- Many systems complement queries with the ability to search words in a given **context**
- Words which appear near each other may signal higher likelihood of relevance than if they appear apart
- We may want to form phrases of words or find words which are proximal in the text
  - Phrase
    - Is a sequence of single-word queries
    - An occurrence of the phrase is a sequence of words
    - Can be ranked in a fashion somewhat analogous to single words
  - Proximity
    - Is a more relaxed version of the phrase query
    - A maximum allowed distance between single words or phrases is given
    - The ranking technique can be depend on physical proximity

Boolean Queries

- The oldest way to combine keyword queries is to use boolean operators
- A **boolean query** has a syntax composed of
  - **atoms**: basic queries that retrieve documents
  - **boolean operators**: work on their operands (which are sets of documents) and deliver sets of documents
- This scheme is in general **compositional**: operators can be composed over the results of other operators

Boolean Queries

- A **query syntax** tree is naturally defined
- Consider the example of a query syntax tree below



- It will retrieve all the documents which contain the word `translation` as well as either the word `syntax` or the word `syntactic`

Boolean Queries

- The operators most commonly used, given two basic queries or boolean sub-expressions e_1 and e_2, are:
  - e_1 **OR** e_2: the query selects all documents which satisfy e_1 or e_2
  - e_1 **AND** e_2: selects all documents which satisfy both e_1 and e_2
  - e_1 **BUT** e_2: selects all documents which satisfy e_1 but not e_2
  - **NOT** e_2: the query selects all documents which not contain e_2

Boolean Queries

- With classic boolean systems, no ranking of the retrieved documents is provided
  - A document either satisfies the boolean query or it does not
- This is quite a limitation because it does not allow for partial matching between a document and a user query
- To overcome this limitation, the condition for retrieval must be relaxed
  - For instance, a document which partially satisfies an AND condition might be retrieved
- The **NOT** operator is usually not used alone as the complement of a set of documents is the rest of the document collection

Boolean Queries

- A **fuzzy-boolean** set of operators has been proposed
- The idea is that the meaning of AND and OR can be relaxed, so that they retrieve more documents
- The documents are ranked higher when they have a larger number of elements in common with the query

Query Languages

Beyond Keywords

Pattern Matching

- A **pattern** is a set of syntactic features that must be found in a text segment
- Those segments satisfying the pattern specifications are said to **match** the pattern
- We can search for documents containing segments which match a given search pattern
- Each system allows specifying some types of patterns
- The more powerful the set of patterns allowed, the more involved queries can the user formulate, in general

Pattern Matching

- The most used types of patterns are:
  - **Words**: a string which must be a word in the text
  - **Prefixes**: a string which must form the beginning of a text word
  - **Suffixes**: a string which must form the termination of a text word
  - **Substrings**: a string which can appear within a text word
  - **Ranges**: a pair of strings which matches any word which lexicographically lies between them
  - **Allowing errors**: a word together with an error threshold
  - **Regular expressions**: a rather general pattern built up by simple strings
  - **Extended patterns**: a more user-friendly query language to represent some common cases of regular expressions

Natural Language

- Pushing the fuzzy model even further, the distinction between AND and OR could be completely blurred
- In this case, a query becomes simply an enumeration of words and context queries
- The negation can be handled by letting the user express that some words are not desired
  - Then the documents containing them are penalized in the ranking computation
- Under this scheme we have completely eliminated any reference to boolean operations and entered into the field of **natural language** queries

Query Languages

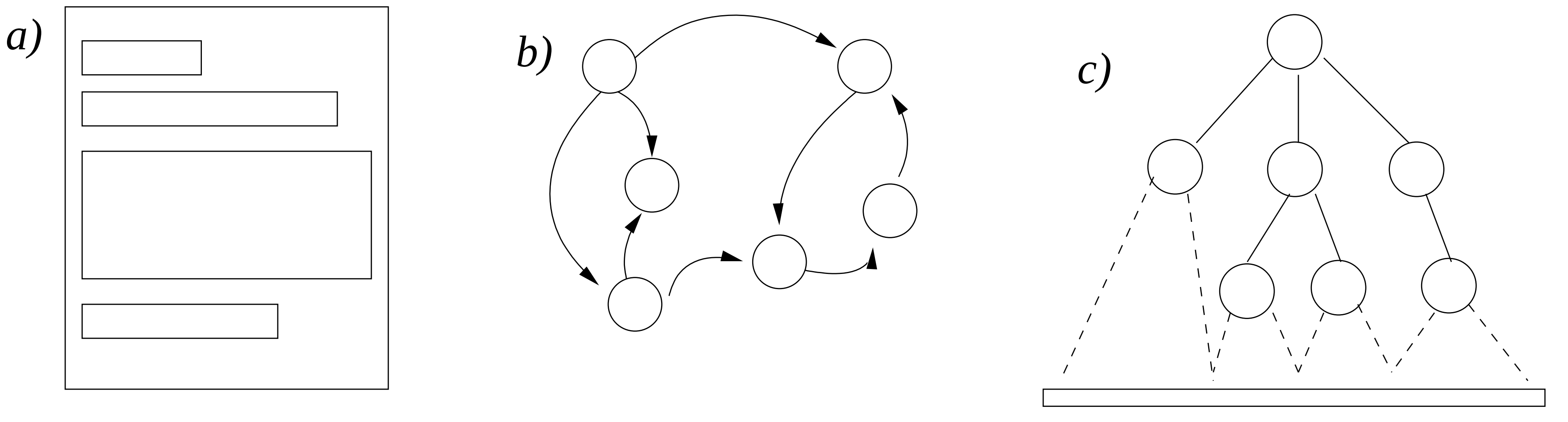
Structural Queries

Structural Queries

- The text collections tend to have some structure built into them
  - The standardization of languages to represent structured texts has pushed forward in this direction
- Mixing contents and structure in queries allows posing very powerful queries
- Queries can be expressed using containment, proximity or other restrictions on the structural elements
- More details in Chapter 13 on Structured Text Retrieval

Structural Queries

- The three main types of structures:
  - $a)$ form-like fixed structure
  - $b)$ hypertext structure
  - $c)$ hierarchical structure



Fixed Structure

- The structure allowed in texts was traditionally quite restrictive
- The documents had a fixed set of fields, and each field had some text inside
  - Some fields were not present in all documents
  - Some documents could have text not classified under any field
  - They were not allowed to nest or overlap
- Retrieval activity allowed: specifying that a given basic pattern was to be found only in a given field

Fixed Structure

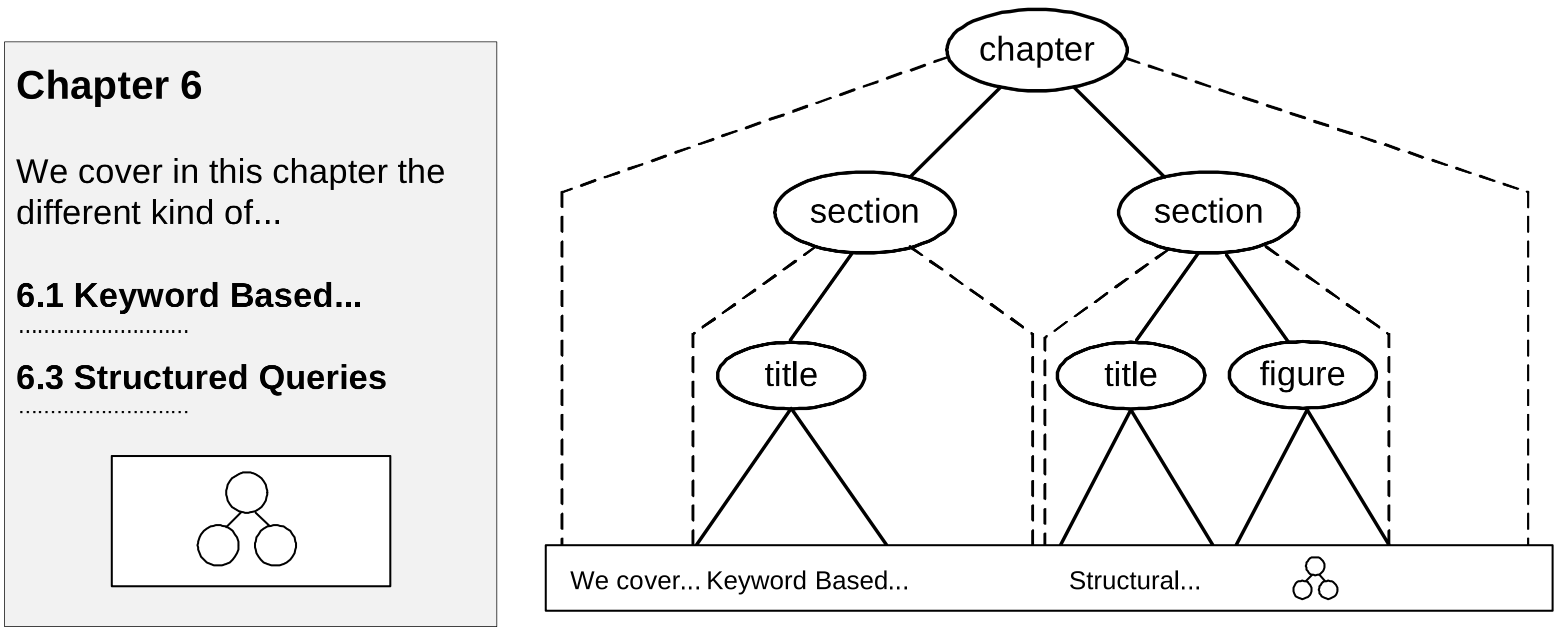
- When the structure is very rigid, the content of some fields can be interpreted as numbers, dates, etc.
- This idea leads naturally to the relational model, each field corresponding to a column in the database table
- There are several proposals that extend SQL to allow full-text retrieval
  - Among them we can mention proposals by the leading relational database vendors such as Oracle and Sybase, as well as SFQL

Fixed Structure

- Hypertexts probably represent the opposite trend with respect to structuring power
- Retrieval from hypertext began as a merely navigational activity
- That is, the user had to manually traverse the hypertext nodes following links to search what he/she wanted
- Some query tools allow querying hypertext based on their content and their structure

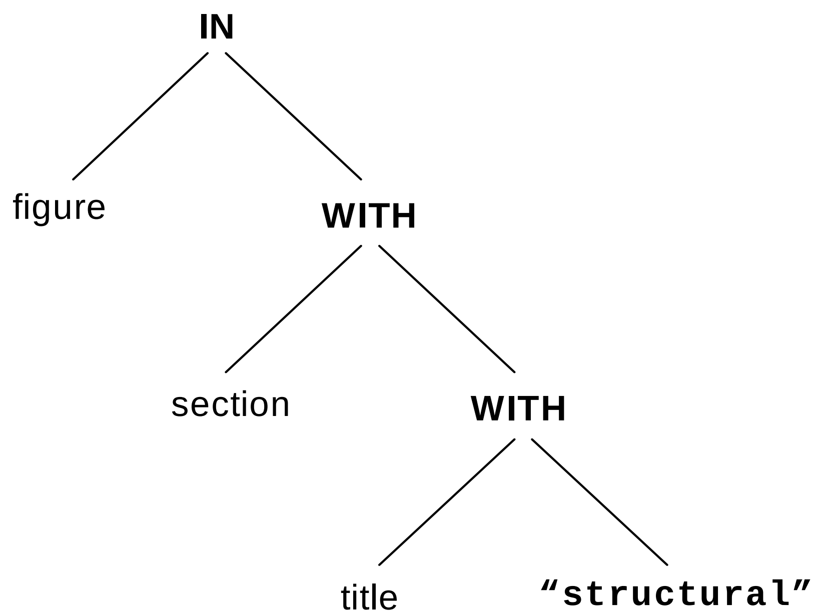
Fixed Structure

- An intermediate model which lies between fixed structure and hypertext is the **hierarchical structure**
- An example of a hierarchical structure: the page of a book and its schematic view

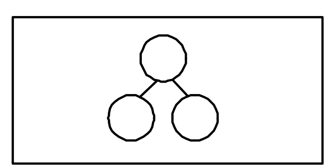


Fixed Structure

- An example of a query to the hierarchical structure presented



- This parsed query returns the image below



Query Languages

Query Protocols

Query Protocols

- Sometimes, query languages are used by applications to query text databases
- Because they are not intended for human use, we refer to them as **protocols** rather than languages
- The most important are/were:
  - **Z39.50**
  - **Wide Area Information Service (WAIS)**

Query Protocols

- In the CD-ROM publishing arena there are several proposals for query protocols
- The main goal of these protocols is to provide **disc interchangeability**
- We can cite three of them:
  - **Common Command Language (CCL)**
  - **Compact Disk Read only Data exchange (CD-RDx)**
  - **Structured Full-text Query Language (SFQL)**
- SFQL is based on SQL and also has a client-server architecture
- The language does not define any specific formatting or markup

Query Protocols

- For example, a query in SFQL is:

```
Select abstract from journal.papers
where title contains "text search"
```

- The language supports boolean and logical operators, thesaurus, proximity operations and some special characters as wild-cards and repetition

- For example:

  `... where paper contains "retrieval" or like "info %" and date` $> 1/1/98$

Query Properties

Characterizing Web Queries

- The notion of **information seeking** encompasses a broad range of **information needs**
- People have different search needs at different times and in different contexts
- A number of researchers have attempted to classify and tally the types of information needs

Characterizing Web Queries

- Most web search engines **record information about the queries**
  - This information includes the **query** itself, the **time**, and the **IP address**
  - Some systems also record which **search results were clicked** on for a given query
- These logs are a valuable resource for understanding the kinds of information needs that users have
- The first studies concentrated on basic statistics:
  - query occurrences
  - term occurrences
  - query length

Characterizing Web Queries

- Jansen & Spink claim a trend of a decreasing percentage of one-word queries
- Jansen *et al* found that the percentage of three word queries increased from 28% in 1998 to 49% in 2002
- In May 2005, Jansen *et al* conducted a study using 1.5M queries gathered from the Dogpile search engine
  - This study found that the mean length of the queries was 2.8 terms, with the longest query having 25 terms
- Results for a larger data set, 185M queries of Yahoo! UK in 2007, were presented by Skobeltsyn *et al*

Characterizing Web Queries

- Table below shows the distribution of query lengths for these two last references

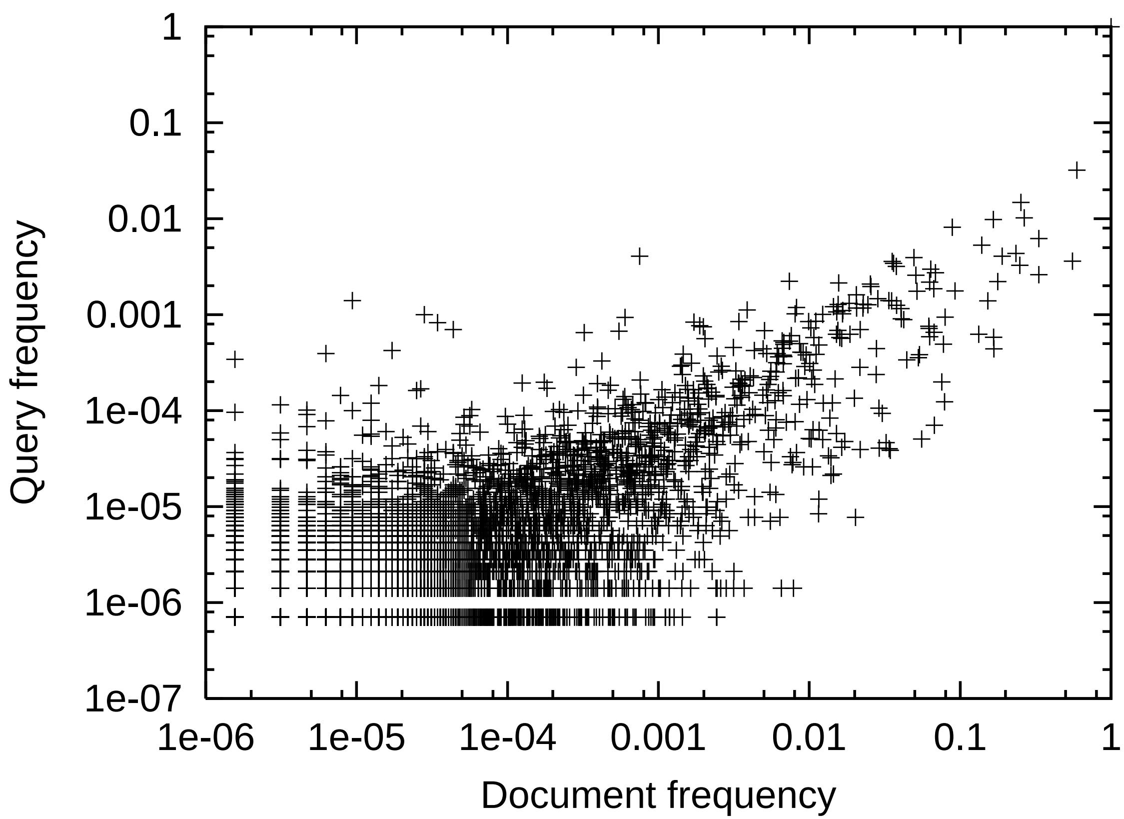
Length	Dogpile (2005)	Yahoo! (2007)
1	18	25
2	32	35
3	25	23
4	13	11
5	6	4
6	3	1
$>$7	3	1

Characterizing Web Queries

- Queries, as words in a text, follow a biased distribution
- In fact, the frequency of query words follow a **Zipf's law** with parameter α
  - The value of α ranges from 0.6 to 1.4, perhaps due to language and cultural differences
- However, this is less biased than Web text, where α is closer to 2
- The standard correlation among the frequency of a word in the Web pages and in the queries also varies
  - These values range from 0.15 to 0.42

Characterizing Web Queries

- This implies that **what people search is different from what people publish in the Web**
- Relative **query frequency** vs. relative **document frequency** of each word in a vocabulary:



Characterizing Web Queries

- Some logs also registers the **number of answer pages seen** and the **pages selected** after a search
- Many people refines the query adding and removing words, but most of them see very few answer pages
- The table below shows query statistics for four different search engines

Measure	AltaVista (1998)	Excite (2001)	AlltheWeb (2001)	TodoCL (2002)
Words per query	2.4	2.6	2.3	1.1
Queries per user	2.0	2.3	2.9	–
Answer pages per query	1.3	1.7	2.2	1.2
Boolean queries	$<$40%	10%	–	16%

Characterizing Web Queries

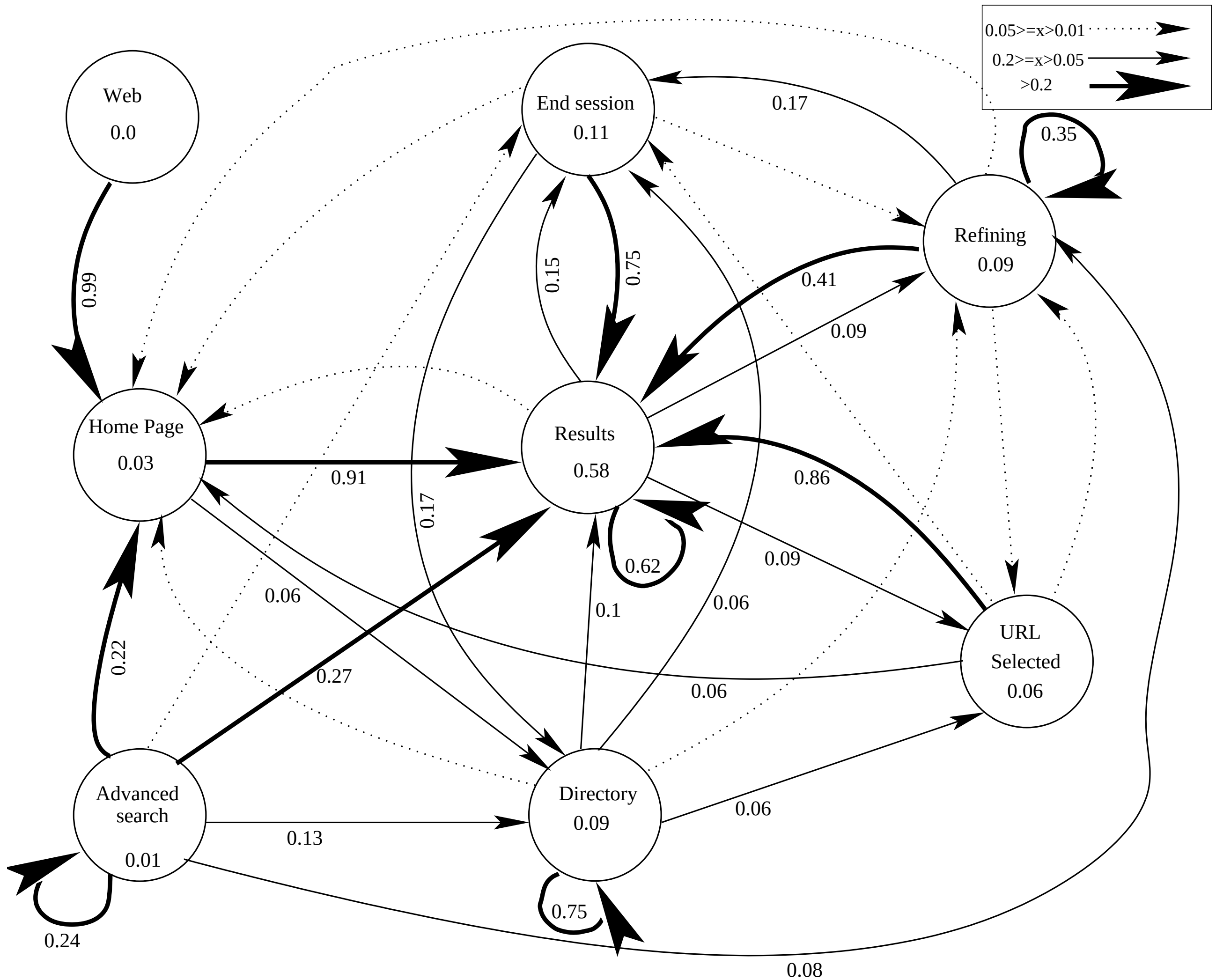
- In addition, the average number of pages clicked per answer can be low due to navigational queries (around 2 clicks per query)
- Further studies have shown that the focus of the queries has shifted from leisure to e-commerce (more details later in the section about Query Topics)

Query Properties

User Search Behavior

User Search Behavior

- State diagram of user behavior in a small search engine



Query Intent

- Until the Web, the concept of a user query was associated with searching for information of interest
- The design of the search tool was always targeted to help the user write good queries
  - This implies that the query language adopted was usually complex
- The Web changed this drastically, as users started to use search engines not only to find information, but also to achieve other goals

Query Intent

- Broder's taxonomy of Web search goals:
  - **Navigational**: The immediate intent is to reach a particular site (24.5% survey, 20% query log)
  - **Informational**: The intent is to acquire some information (39% survey, 48% query log)
  - **Transactional**: The intent is to perform some web-mediated activity (36% survey, 30% query log)
- This taxonomy has been heavily influential in discussions of query types on the Web

Query Intent

- Rose & Levinson developed a taxonomy that extended and changed somewhat from Broder's
- They noted that much of what happens on the Web is the acquisition and consumption of online resources
- Thus they replace Broder's transactions category with a broader category of **resources**

Query Intent

- Recent research have dealt with the automatic prediction of these classes
- These works use machine learning over different query attributes such as:
  - Anchor-text distribution of the words in the queries
  - Past click behavior
- The main problem is that many queries are **inherently ambiguous**
  - They can be classified in more than one class when the context of the search is not known

Query Topic

- Queries can also be classified according to the topic of the query, independently of the query intent
- For example, a search involving the topic of weather can consist of:
  - the simple information need of looking at today's forecast, or
  - the rich and complex information need of studying meteorology

Query Topic

- Spink & Jansen *et al* have manually analyzed samples of query logs
  - The authors found that queries relating to sex and pornography declined from 16.8% in 1997 to just 3.6% in 2005
  - On the other hand, commerce-related queries increased from 13% to almost 25% in the same years

Query Topic

- Changes in Excite topics from 1997 to 2001 (%)

Rank	Topic	1997	2001
1	Commerce, travel, employment, or economy	13.3	24.7
2	People, places, or things	6.7	19.7
3	Non-English or unknown	4.1	11.3
4	Computers or Internet	12.5	9.6
5	Sex or pornography	16.8	8.5
6	Health or sciences	9.5	7.5
7	Entertainment or recreation	19.9	6.6
8	Education or humanities	5.6	4.5
9	Society, culture, ethnicity, or religion	5.4	3.9
10	Government	3.4	2.0
11	Performing or fine arts	5.4	1.1

Query Topic

- Shen *et al* mapped the results of a search engine to the set of categories in the Open Directory Project
  - Their results: F-score of about .45 on 63 categories
- The table below shows the results for five queries

Query	Top category	Second category
chat rooms	Computers/Internet	Online Community/Chat
lake michigan lodges	Info/Local & Regional	Living/Travel & Vacation
stephen hawking	Info/Science & Tech	Info/Arts & Humanities
dog shampoo	Shopping/Buying Guides	Living/Pets & Animals
text mining	Computers/Software	Information/Companies

Query Topic

- Broder *et al* presented a method for classifying short, rare queries into a taxonomy of 6,000 categories
  - This is an important problem because rare or infrequent queries are approximately half of all queries
- Training data: a commercial taxonomy containing many documents assigned to each category
- They classified the results of a query in the classifier, and then used a voting algorithm to classify the query

Query Topic

- Ambiguous queries are those queries that can have two or more distinct meanings
  - For instance, a query can be related to politics but also to news
- There are few papers for ambiguity detection
- Song *et al* estimated that about 16% of all queries are ambiguous

Query Sessions and Missions

- One important problem when analyzing queries is determining user query sessions
- Early work used fixed limits of time to define sessions, but this definition presents two problems:
  - the session might be longer
  - the goals of the user in the session might be more than one
- Hence, it is good to distinguish
  - time based sessions: queries of a user in a same session
  - missions: sequence of queries with the same goal
- **Research missions**: an additional problem is that missions can span more than one session

Query Session Boundaries

- One alternative to determine sessions more accurately is to establish a **maximum inactivity time**
  - Different authors have found different thresholds ranging from five to sixty minutes
- **Query missions** are a sequence of reformulated queries that express a same need
- The detection of missions is a hard problem and has been approached by several researchers

Query Properties

Query Difficulty

Query Difficulty

- Another important characteristic of queries is their intrinsic difficulty
  - For example, one word queries are simpler than phrase queries
- There are two different ways to measure difficulty
  - **Post-retrieval predictions mechanisms**: run the query and analyze its answer set
  - **Pre-retrieval mechanisms**: evaluate the difficulty without executing the query

Post-retrieval Algorithms

- Post-retrieval algorithms are more diverse as they have more information at hand
- **Clarity Score** relies on the difference between the language models of the collection and of the top retrieved documents
- The intuition is that the top ranked results of an unambiguous query will be topically cohesive
- Term distribution of an ambiguous query is assumed to be more similar to the collection distribution

Post-retrieval Algorithms

- Yom-Tov *et al* compared the ranked list of the original query with the ranked lists of the query's terms
  - Intuition: for well performing queries, the results do not change considerably if only a subset of query terms is used
- Aslam *et al*: a query is considered to be difficult if different ranking functions retrieve diverse ranked lists
  - If the overlap between the top ranked documents is large across all ranked lists, the query is deemed to be easy

Post-retrieval Algorithms

- Zhou and Croft investigated two approaches: Weighted Information Gain and Query Feedback
- **Weighted Information Gain** measures the change in information about the quality of retrieval between:
  - an imaginary state that only an average document is retrieved (estimated by the collection model), and
  - a posterior state where the actual search results are observed

Post-retrieval Algorithms

- **Query Feedback** frames query prediction as a communication channel problem
  - The input is query Q, the channel is the retrieval system, and the ranked list L is the noisy output of the channel
  - From L, a new query Q' is generated, a second ranking L' is retrieved with Q'
  - The overlap between L and L' is used as prediction score
- Hauff *et al* provides an evaluation of these techniques and propose a new technique named **Improved Clarity**

Pre-retrieval Algorithms

- Pre-retrieval algorithms must rely on the collection statistics of the query terms to predict query difficulty
- For example, they either take into account:
  - the frequencies of the query terms in the collection, such as **Averaged IDF** or **Simplified Clarity Score**, or
  - the co-occurrence of query terms in the collection, such as **Averaged Pointwise Mutual Information** (PMI)
- Kwok *et al* proposed measures based on the inverse document frequency and the collection frequency
- Queries with low frequency terms are predicted to achieve a better performance

Pre-retrieval Algorithms

- He *et al* evaluated a number of algorithms, including Query Scope and Simplified Clarity Score
- **Query Scope** uses the number of documents in the collection that contain at least one of the query terms
- **Simplified Clarity Score (SCS)** relies on term frequencies:

$$SCS(q) = \sum_{k_i \in q} P_{ml}(k_i|q) \times \log_2 \left(\frac{P_{ml}(k_i|q)}{P_{coll}(k_i)} \right)$$

  where

  - $P_{ml}(k_i|q)$ is the maximum likelihood estimator of term k_i given query q
  - $P_{coll}(k_i)$ is the term count of k_i in the collection divided by the total number of terms in the collection

Pre-retrieval Algorithms

- *Averaged PMI* measures the **average mutual information** of two query terms in the collection:

$$AvPMI(q) = \frac{1}{|(k_i, k_\ell)|} \sum_{(k_i, k_\ell) \in q} \log_2 \left(\frac{P_{coll}(k_i, k_\ell)}{P_{coll}(k_i) P_{coll}(k_\ell)} \right)$$

  where $P_{coll}(k_i, k_\ell)$ is the probability that terms k_i and k_ℓ occur in the same document

Pre-retrieval Algorithms

- Pre-retrieval predictors usually have a lower accuracy compared to post-retrieval predictors
- This is because the information available to them is much more general and much more sparse
- Nevertheless, two pre-retrieval predictors achieve performance equivalent to post-retrieval predictors
- Both approaches are computationally intensive:
  - The technique proposed by He *et al* requires clustering
  - The technique proposed by Zhao *et al* requires determining the *tf.idf* distribution of all documents
- However, both techniques are not efficient enough to be useful for large collections